The *Lancet* One Health Commission: harnessing our interconnectedness for equitable, sustainable, and healthy socioecological systems

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Executive summary

Industrialisation, urbanisation, and globalisation have substantially improved human life expectancy over the past century. In tandem, an expanding array of interlinked threats to humans, other animals, plants, and a myriad of other biotic and abiotic elements in our shared ecosystems has been generated. These threats include emerging and re-emerging infectious diseases, antimicrobial resistance (AMR), non-communicable diseases (NCDs), jeopardised food safety and security, freshwater scarcity, climate change, pollution, and biodiversity loss. These pressing health and sustainability challenges exceed the scope of any single discipline, government ministry, or societal sector, underscoring the need for interdisciplinary, transdisciplinary, and multisectoral collaboration, as well as for a socioecologically oriented systems perspective that appreciates the fundamental interconnections between humans, other animals, and the wider ecosystem.

When this Commission first convened in 2019, One Health was a highly visible, but also greatly evolving, concept and approach. Predominantly driven by the veterinary sector, the primary focus of One Health in early years had been on zoonotic diseases, but more recent years have seen an increasingly interdisciplinary and transdisciplinary expansion and diversification of the concept, a proliferation of initiatives, and growing concerns about fragmentation and insufficient conceptual clarity. There was a need to advance not only conceptual expansion, but also consensus, as well as aligned, interdisciplinary, transdisciplinary, and multisectoral efforts towards One Health operationalisation, implementation, and institutionalisation. We set out to address these needs and leverage One Health as a crucial and viable approach to achieving equitable, sustainable, and healthy socioecological systems—the vision of the *Lancet* One Health Commission. The zoonotic underpinnings of the COVID-19 pandemic and its wide-ranging effects across sectors necessitated a radical rethink of the role of One Health in pursuing sustainable development and substantially shaped the importance and trajectories of the Commission's work.

The Commission's methodology entailed convening a diverse, transnational, and interdisciplinary group of experts, who conducted an informed synthesis and appraisal of the current state of knowledge and evidence regarding the need for and value of One Health, which resulted in the proposal of key avenues for One Health operationalisation, implementation, and institutionalisation. We build on new and evolving One Health advances, including the One Health Joint Plan of Action, launched by the One Health Quadripartite, and the definition of One Health, One Health principles, and theory of change put forth by the One Health High-Level Expert Panel (OHHLEP).

This Commission is guided by a One Health ethos comprising principles of holism and systems thinking, epistemological pluralism, equity and egalitarianism, and stewardship and sustainability. The Commission also engages a socioecological systems perspective that sheds light on the crucial importance of the environment, including plants, soil, water, air, wildlife, biodiversity, and climate. In our approach, we have deliberately avoided boundaries between humans, other animals, and the environment. As reflected in the key messages, the evidence synthesis and appraisal was structured via sections dedicated to surveillance, infectious diseases, AMR, NCDs, health systems, and food systems.

The *Lancet* One Health Commission provides a cutting-edge appraisal of where One Health has come from, where it is now, and what a viable future should be. One Health was not mentioned in the 2030 Sustainable Development Agenda; however, the impact of the COVID-19 pandemic brought into acute focus the fundamental interconnections between humans, other animals, plants, and a myriad of other biotic and abiotic elements in the ecosystem, and, consequently, how healthy sustainable socioecological systems could be achieved via a One Health approach. The consensus around One Health that has been built by the One Health Quadripartite and OHHLEP, which has been reinforced by this Commission, is essential for addressing the threats to health posed by infectious diseases, AMR, NCDs, and planetary crises; harnessing data and artificial intelligence for disease surveillance and health-care delivery; forging equitable partnerships and inclusive collaborations; and generating necessary insight into socioecological interconnection. As such, One Health is a crucial catalyst in the pursuit of an equitable, sustainable,

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Key messages

Expanding the One Health concept

Since the concept first emerged in the early 2000s, One Health has been defined and engaged with in many different ways. For many years, it was driven by the veterinary sector and predominantly focused on concerns about zoonotic disease transmission at the human–animal interface. In the wake of the COVID-19 pandemic in particular, the concept has been expanding. In supporting this expansion, this Commission asserts that One Health is an interdisciplinary, transdisciplinary, and multisectoral approach to addressing pressing global health and sustainability challenges and promoting equitable, sustainable, and healthy socioecological systems. One Health, as conceived by this Commission, is grounded in an appreciation of the fundamental interconnectedness and health interdependencies among humans, other animals, plants, and a myriad of other biotic and abiotic elements in the wider ecosystem.

The socioecological systems perspective

Socioecological interconnection among humans, other animals, plants, and the wider environment is the foundation of One Health. The triple planetary crisis of climate change, biodiversity loss, and pollution poses serious threats to health and sustainability. Climate change mitigation, biodiversity conservation, and ecological restoration must be prioritised within the One Health approach.

Surveillance

More effective disease surveillance is needed, and can be achieved through an integrated One Health approach. However, the availability and quality of data can vary greatly across sectors and, even where data exist, key challenges linked to data sharing and integration must be addressed. Moreover, a One Health approach to surveillance provides unique opportunities to monitor not only threats, but also the preconditions for health and determinants of healthy and sustainable systems, thereby supporting resilient ecosystems and health-promoting environments.

Infectious diseases

A One Health approach to infectious diseases must address not only zoonotic diseases of pandemic potential, but also neglected tropical diseases and the effect of infectious animal diseases on the health of livestock, wildlife (terrestrial and aquatic animal, plant, and insect species), companion animals, food systems and nutrition, antimicrobial use, livelihoods, and economic development.

Antimicrobial resistance

The One Health approach to antimicrobial resistance must emphasise environmental drivers, which this Commission has found to differ across high-income countries and low-income and middle-income countries. This Commission also asserts a need to prioritise equitable access to effective antimicrobials globally, stewardship, community-centred approaches to national priority setting, and upscaling of investment in the most effective interventions, such as improved infection prevention and control; water, sanitation, and hygiene; and vaccination programmes across both human and animal health systems.

Non-communicable diseases

Non-communicable diseases have traditionally received little attention within One Health research and practice, which this Commission seeks to change. A One Health approach to non-communicable diseases enables a systematic understanding and equitable approach to addressing the shared risk factors (eg, environmental pollutants, unhealthy diets, and climate change) and other determinants of health and wellbeing across species and throughout the socioecological system. Multisectoral, inclusive, and equitable collaboration for One Health governance, including joint agenda-setting and policy, is indispensable for holistic and sustainable prevention and management of non-communicable diseases.

Health systems and health-promoting synergies

A One Health approach to interventions (eg, diagnostics, medicines, vaccines, and similar strategies for promoting health and preventing disease) entails collaboration across two or more sectors and disciplines to harness health-promoting synergies and holistically advance health and wellbeing throughout the socioecological system. Inclusive processes that prioritise community engagement can facilitate context-adapted interventions. Interventions with multispecies applicability can also be cost-effective. The added value of One Health interventions needs to be demonstrated through relevant metrics, and evaluation and decision support frameworks should account for not only the wellbeing of humans, but also that of animals and the environment.

Food systems

The One Health approach is important for navigating the complexity of food systems challenges, for cultivating unifying values around roles and responsibilities, and, ultimately, for informing and realising the systemic changes that are necessary to deliver food safety and security in globally and intergenerationally equitable ways. A transformation towards healthy, sustainable, safe, and equitable food systems demands attention to financialisation and corporate dominance. Corporate actors must be engaged to address the conflict between profit and sustainability from a global perspective, while taking local ramifications into consideration. Understanding of food production systems must also go beyond linear analyses of value and supply chains. There is a need for greater awareness of food production inputs, such as feed, medications, and water sources, as well as of post-farm processes, such as food transport and processing, including the management of waste and contaminants. One Health provides a holistic approach to addressing food production and waste challenges, while supporting the billions of lives and livelihoods that are at stake.

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Governance

The Commission asserts that One Health plays a pivotal role in the global health and sustainability agendas of the 21st century and beyond, by galvanising transformations within global governance, economics and finance, and knowledge in service to equitable, sustainable, and healthy socioecological systems. For governance, the Commission recommends the integration of One Health within the global, regional, and national governance structures. At the global level, this integration demands a One Health governance framework. The One Health Quadripartite and One Health High-Level Expert Panel could evolve to address this need, if sufficiently resourced with adequate funds, a full-time workforce, and legal authority. At the national and regional levels, all government ministries, together with relevant sectors and stakeholders, should continue to develop and implement One Health-guided governance reforms, including what this Commission conceives of as One Health in All Policies. At all governance levels, collaboration across disciplines and sectors, participatory approaches that prioritise community engagement, and diversity are needed.

Economics

There is overwhelming evidence supporting the cost-effectiveness of One Health interventions relative to non-One Health alternatives. The Commission posits that the prevailing, anthropocentrically oriented global economic system, in which growth is measured in terms of gross domestic product (GDP), is inherently antithetical to the One Health goal of equitable, sustainable, and healthy socioecological systems. In addition to the urgent need to explore alternatives to economic paradigms anchored in GDP-growth economics, such as Doughnut Economics, the Circular Economy, and the Wellbeing Economy, the Commission endorses the recent high-level rethinking of the relationship between sustainability, wellbeing, and the global economy that has been advanced by the WHO Council on the Economics of Health For All. The Commission calls for a slow, yet radical, paradigm shift in local, national, and international budgetary allocations, innovative financing of One Health initiatives, and novel economic frameworks focused on realising and sustaining healthy socioecological systems.

Knowledge

The Commission asserts the importance of equitable and inclusive practices of knowledge production, integration, and sharing that yield a diverse cadre of competent professionals and empowered citizens who espouse One Health values and who generate transformative, systemic change for the achievement of sustainable health throughout the socioecological system. This includes mainstreaming One Health throughout the higher education sector, by adopting a core set of One Health competencies and cultivating enabling conditions for One Health research, with measures of success that include social and policy impact. Achieving a global citizenry literate in One Health requires the integration of diverse knowledge systems, including Indigenous knowledge, intergenerational knowledge exchange, and the translation of knowledge into action.

and healthy future, and must be central to the post-2030 global health and sustainability agenda.

Introduction

Background

Humans, other animals, plants, and a myriad of other biotic and abiotic elements in our shared ecosystems are fundamentally interconnected. Although the nature of our inter-relation varies over time and across species and cultures, recent centuries are distinguished by unprecedented human impact and formidable transformations, including industrialisation, urbanisation, and globalisation. These developmental trajectories have advanced health markedly, but largely at the expense of equity and sustainability, and they have generated an expanding array of interlinked threats to health and wellbeing throughout the socioecological system. Climate change is accelerating, biodiversity is declining, crises of food insecurity and freshwater scarcity are progressing, and the impact of infectious diseases, non-communicable diseases (NCDs), and antimicrobial resistance (AMR) is increasing.

As a global society, how we understand and respond to current and impending health and sustainability crises is of enduring consequence for future generations and for the socioecological system at large. This Commission calls for collective action and systemic transformation, guided by a One Health perspective and approach. One Health advances an established and expanding interdisciplinary and transdisciplinary understanding of the fundamental interconnectedness and health interdependencies among humans, other animals, plants, and a myriad of other biotic and abiotic elements in the ecosystem, as well as a multisectoral approach to addressing the pressing global health and sustainability challenges of contemporary times and to realising and sustaining healthy socioecological systems.

The *Lancet* One Health Commission

The vision of the *Lancet* One Health Commission is healthy socioecological systems, achieved and sustained through an equity oriented, interdisciplinary, transdisciplinary, and multisectoral One Health approach to advancing health among humans, other animals, plants, other biological

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Panel 1: Glossary

Added value

Added value, in the context of One Health and this Commission, refers to increased benefit in the form of more efficient improvements to health among humans, other animals, plants, and the wider ecosystem, achieved through interdisciplinary, transdisciplinary, and multisectoral collaboration, versus siloed approaches.[1,2] Efficiency is understood as the optimal ratio between maximum effect or impact and minimal effort and resources.

Anthropocentricism

Anthropocentricism is a human-centric paradigm. Humans are understood as the central and most important entity of existence, and the rest of the living and non-living world are regarded from the vantage point of human experience and values.[3]

Biodiversity

Biodiversity refers to the multitude of and variation among all life on earth, including genes, species, and ecosystems.[4]

Epistemology and ontology

Epistemology can be understood as the theory of knowledge, including the nature of truth and the conditions of knowing. Ontology can be understood as the theory of reality, including the nature of being and the relations between the entities that are said to exist. Natural sciences lean towards positivist paradigms, which are epistemologically and ontologically oriented towards objective facts. These facts include patterns of cause and effect that are understood to exist independently of the researcher, which the researcher seeks to uncover, often through quantitative methods that prioritise objectivity, including by controlling for variables and biases. Much of the social sciences, however, lean towards interpretivist paradigms, which are epistemologically and ontologically oriented towards the social construction of reality. This includes the coexistence of multiple and situated subjective truths, insight into which is commonly generated through often qualitative methods that prioritise the coproduction of meaning, including through dialogue and interaction. Thus, although disciplines structure scientific and academic activities in important ways, interdisciplinary and transdisciplinary collaboration is needed.

Ecocentrism

Ecocentrism is an ecosystem-oriented paradigm in which all entities of the biosphere are attributed inherent value and recognised for the role that they play in the ecological cycle of life. Biocentrism is similar to ecocentrism but extends inherent value to all living elements of the ecosystem, as opposed to all living and non-living elements.[5]

Ecosystem

An ecosystem is a community of biotic and abiotic interactions, nutrient cycles, and energy flows comprising animals (including humans and insects), plants, and the life-supporting physical and chemical resources of the water, land, atmosphere, and sun.[6]

Ecosystem services

Ecosystem services are the benefits provided by ecosystems that support human life and advance human wellbeing. Examples include the provision of water, food, air, shelter, and fuel; the regulation of climate, waste, and disease; and the cultural, spiritual, and recreational value of nature.[6]

Environment

A natural environment is often understood as a space, free from human intervention, in which the abiotic and biotic elements of the ecological world exist and interact. The built environment refers to the human-made structures and features of the spaces in which humans operate. The natural–built environment dichotomy, as well as the indoor–outdoor dichotomy that tends to follow, is conceptually helpful to some extent, but also inherently problematic. Elements of natural and built environments coexist in the same spaces, and the human drive to dwell and thus build can also be understood as natural.[7] Environments are shaped by interactions between the ecological and social, thus underscoring the use of a socioecological systems perspective.

Equality and equity

Although the terms equality and equity are often used interchangeably and inconsistently, equality can be understood as an identical distribution of opportunity and resources, whereas equity entails recognising the social inequalities that exist and distributing resources and opportunities proportional to that which is needed to have equally positive outcomes for all.[8] Intersectionality is the theory of how multiple inequalities among humans intersect along lines of, for example, ethnicity, race, gender, ability, sexuality, nationality, and religion.[9] Moreover, calls for decolonisation seek to not merely redistribute within the social system that exists, but rather to dismantle the historically entrenched and socially institutionalised dynamics of power and discrimination that systematically privilege some demographics and disadvantage others.[10,11]

Interdisciplinarity and transdisciplinarity

In this Commission, we advocate for interdisciplinarity and transdisciplinarity, which we regard as entailing an interdisciplinary integration and synthesis of knowledge and methods from multiple disciplines, as well as a transdisciplinary transcendence of disciplinary boundaries and a participatory approach to integrating expertise from beyond academia and science, such as from members of local communities.[12]

Multisectoralism and multisectoral coordinating mechanisms

In the context of One Health, which is per definition a multisectoral approach, multisectoralism is a call for collaboration between all relevant sectors, including between the human, animal, and environmental sectors, and between the public sector, the private sector, and civil society. Multisectoral coordination mechanisms are established to support and advance this collaboration.[13]

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One Health
One Health is an interdisciplinary, transdisciplinary, and multisectoral approach to addressing global health and sustainability challenges and to advancing equitable, sustainable, and healthy socioecological systems. The foundation of the One Health approach is the fundamental interconnectedness of humans, other animals (terrestrial, aquatic, domesticated, and wild), plants, other biological kingdoms (including fungi), and all other biotic and abiotic entities in the ecosystems that we are part of and share (including soil, water, air). The principles that make up the One Health ethos espoused by this Commission are holism and systems thinking, epistemological pluralism, equity and egalitarianism, and stewardship and sustainability.

Resilience
In a socioecological perspective, resilience refers to an adaptive capacity for dynamic balance, in which crucial functions are maintained in transformation.[14]

Socioecological system
A socioecological system comprises the diverse, complex, and dynamic inter-relations and interdependencies between and among the ecological systems of the natural world and the social, cultural, political, and economic systems of the human-constructed world.[15]

Sustainability and sustainable development
Sustainability can be understood as the balance between economic, social, and environmental interests that is necessary to enable humans, other animals, plants, and the wider ecosystem to coexist and thrive over time. Sustainable development is the process through which the needs of the present are met without compromising the possibilities for meeting these same needs in the future.[16]

kingdoms, and the environment at large, including soil, water, and air. In developing this Commission, we had three main objectives.

First, we aimed to generate insight into the complex socioecological relationships between humans, other animals, plants, and all other biotic and abiotic elements of the shared environment. We also aimed to explicate the importance of these inter-relations for sustainability and health throughout the socioecological system.

Second, we aimed to synthesise and appraise the current state of knowledge and evidence regarding the need for and value of One Health for addressing health and sustainability challenges, with an emphasis on surveillance, infectious diseases, AMR, NCDs, and food systems. We also aimed to identify knowledge gaps and priorities for advancing and sustaining health throughout the socioecological system.

Third, we aimed to propose avenues for One Health operationalisation, with a focus on governance, economics, and knowledge. We also aimed to explicate the pivotal role that One Health can play in 21st-century health and sustainability agendas, as well as its centrality to the transformed socioecological horizon that lies ahead.

A glossary of terms can be found in panel 1.

The historical and cross-cultural foundations of One Health

The socioecological interconnections that underpin One Health have historically rooted and diverse cross-cultural importance. Buddhist doctrines of interbeing and non-violence promote compassionate and peaceful coexistence with nature and among all living beings.[17,18] The Indigenous cultures of the world are also, although heterogeneous, rooted in a shared fundament of harmonious inter-relation between and among humans and the natural world.[19,20] Among ancient Egyptians, animals were revered as sacred deities, mummified together with humans, and laid to rest in shared tombs.[21] Saint Francis of Assisi, the Christian patron saint of animals and the environment, loved animals as brothers and sisters and advocated for their welfare.[22] Socioecological harmony and the rights to health and wellbeing of animals are also embedded in the foundational teachings of Islam and Judaism.[23–25] Mahatma Gandhi, the Hindu leader of India's peaceful independence movement, is known to have linked the moral advancement and greatness of a nation to the way its animals are treated.[26]

The relationships between humans and plants have a rich history as well, with theological, philosophical, and historical underpinnings spanning diverse civilizations, cultures, and religions.[27] These relationships include the influence of plants on the arts and literature, as seen in the tree of life symbolism, which signifies similar understandings and values around the world,[28] and as seen throughout Greek and Roman mythology.[29] The oldest recorded evidence of the medicinal value of plants is a collection of recipes inscribed on a Sumerian clay tablet. Throughout ancient history, many contributions to plant medicine can be recognised, including the foundational work *De Materia Medica*, written by Dioscorides, who is regarded as the father of pharmacognosy.[30]

Within the histories of biomedicine, appreciation of socioecological health interdependencies extends back to 400 BCE, when Hippocrates, and subsequently Plato, Aristotle, and Galen, investigated the effect of the

environment on health.[31–35] During the same period, the study of animal anatomy, animal diseases, and cross-species commonalities paved the way for comparative medicine.[33,36]

Between the years 1600 and 2000, several veterinary and human health advances took place, which can be recognised today as One Health precursors. Italian physician Giovanni Lancisi (1654–1720) examined the role of the environment in pathogen transmission among animals and humans, French veterinary surgeon Claude Bourgelat (1712–79) established the world's first veterinary faculty,[36] and German physician Rudolf Virchow (1821–1902) coined the term zoonosis and proclaimed, "there is no scientific barrier, nor should there be, between veterinary medicine and human medicine; the experience of one must be utilized for the development of the other".[37]

In the 1900s, American veterinarian James H Steele and Canadian physician William Osler improved understanding of pathogen transmission between animals and humans and of the links between human and veterinary medicine.[38,39] In 1964, veterinary public health expert Calvin Schwabe called for collaboration between the medical and veterinary professions and coined the concept One Medicine, which gained momentum in the 21st century and set the stage for the emergence of the One Health concept.[40] In 1962, American ecologist Rachel Carson published the book *Silent Spring*, which raised awareness of the destructive human impact on nature and galvanised the environmental movement.[41,42] In 1977, Kenyan professor of veterinary anatomy Wangari Maathai founded The Green Belt Movement, which empowered women and their communities to improve their livelihoods through environmental conservation and raised international awareness of the links between environmental destruction, deforestation, and food insecurity on the one hand, and disempowerment and disenfranchisement on the other.[43]

Contemporary currents in One Health

The fundamental assertion that there is just one health, based on the premise that a siloed consideration of human, livestock, or wildlife health is not tenable, surfaced in a news article about Ebola in 2003.[44] The term One Health was officially coined at a conference the following year.[45] This conference also inspired the Manhattan Principles, which comprise 12 recommendations for holistic approaches to preventing zoonotic disease epidemics and promoting ecosystem integrity.[46] In the biomedical literature, the term One Health first appeared in 2005, in a *Lancet* publication calling for the One Health approach.[47,48] In the time since, the Manhattan Principles have been revised and expanded by the Berlin Principles,[49] One Health initiatives and networks have proliferated around the world,[50] and the World Bank has endorsed the economic value of One Health.[51] One Health has also been institutionalised at various levels of academia and government, including through the 2010 agreement between the Food and Agriculture Organization of the UN (FAO), the World Organisation for Animal Health (WOAH), and WHO to collaborate closely at the human–animal–environment interface.[52] This tripartite agreement evolved into a quadripartite partnership in 2022, following the incorporation of the UN Environment Programme (UNEP).[53] In conjunction, the One Health High-Level Expert Panel (OHHLEP) was founded.[54]

Because of its biomedically driven recent history, One Health has traditionally leaned towards positivist paradigms that emphasise objective facts (panel 1). Moreover, despite its long-standing conceptual foundation of human–animal–environment interconnection, One Health scholarship has predominantly focused on infectious diseases of zoonotic origin, collaboration between the human and veterinary health sectors, and, more recently, AMR. NCDs have so far been neglected. Although One Health is progressing towards interdisciplinarity, transdisciplinarity, and systems thinking,[55–56] a need remains to integrate the social sciences and humanities more extensively;[57] deepen understanding of the socioecological drivers of health among humans, other animals, plants, and the environment at large; and prioritise community participation. Increasing emphasis has been placed on a broad spectrum of health and sustainability concerns linked to biodiversity, climate, environment, and food and water security.[58]

The value of Indigenous knowledge for One Health is also increasingly appreciated. An increase in One Health partnerships that include Indigenous peoples has been called for,[19,20,59,60] and crucial attention has been directed to the relationship between knowledge and power; to colonial legacies of poverty, health inequity, and intersectional vulnerability; and to the importance of epistemological pluralism for decolonising global health and advancing One Health.[20,61] Notably, despite constituting approximately 5% of the global population, Indigenous people have sustained 80% of the world's biodiversity on the land that they occupy globally (approximately 22%),[62] which also intersects with 40% of the world's protected areas and ecologically preserved landscapes.[63] This ecological conservation has been largely attributed to the harmonious socioecological inter-relations, conservation values, and environmental stewardship that are inherent to many Indigenous worldviews, cultures, and systems of governance.[19,20] Inclusion of local communities more broadly, with appreciation of the substantial knowledge they possess, is crucial.

The 2030 Sustainable Development Agenda, represented by the 17 Sustainable Development Goals established in 2015, is among the previous decade's most overt expressions of global consensus around the interdependent relationship between health, sustainability, and global prosperity. The Sustainable

Development Agenda and One Health are inherently aligned, with One Health elucidating the human–animal–environment interconnections at the core of each goal. However, progress towards the ambitious and widely endorsed, but not legally binding, targets has been insufficient, largely due to weak accountability and little

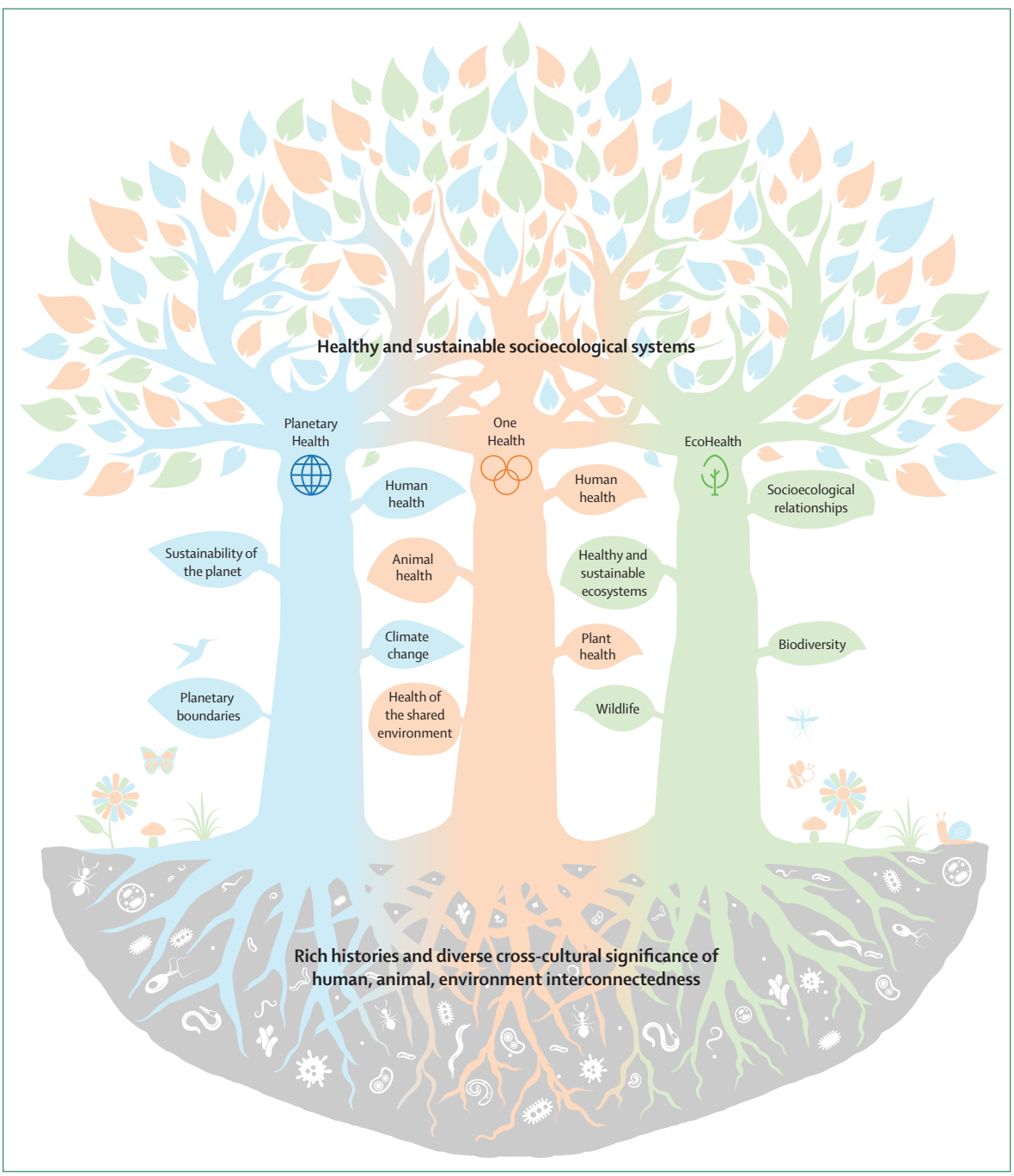

Figure 1: **Integrated approaches to achieving healthy and sustainable socioecological systems**
Planetary Health focuses on the relationship between humans and the natural systems on which human health depends, as regulated by the nine planetary boundaries.[64] Planetary Health is premised on the proposal that we have entered a new planetary epoch, known as the Anthropocene,[65] in which these life-sustaining systems have been fundamentally altered by human activity, with such rapidity that human health and wellbeing are potentially threatened. EcoHealth seeks to understand health in the context of socioecological relationships, with the aim of achieving sustainable health throughout the ecosystem. Biodiversity and equity are core values.[66,67] Although multiple perspectives coexist within and between each of these fields, and although each has evolved and diversified, this figure depicts some of the conventional foci of Planetary Health, One Health, and EcoHealth, which all advance a holistic perspective on socioecological health interdependencies, generate insight into socioecological interconnection, and contribute to a shared ambition of healthy and sustainable socioecological systems.

translation into policy and financing. Systemic transformations in governance, economics, and knowledge will be crucial as 2030 approaches and in the future beyond. One Health, as will be shown in this Commission, must play a central role.

An overview of the Commission

This Commission draws on the knowledge advanced by several *Lancet* Commissions, including on health and climate change, planetary health, healthy diets from sustainable food systems, and global governance for health. We also build on the One Health Series published in *The Lancet* and the work of numerous high-level organisations, including WHO, FAO, WOAH, and UNEP; the One Health Quadripartite that they constitute; the World Bank; the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES); and the Intergovernmental Panel on Climate Change (IPCC). In sections 1–6, we synthesise and appraise the robust and growing scientific evidence base for One Health, with an emphasis on infectious diseases, AMR, and NCDs. We also examine the established added value of One Health and elucidate remaining knowledge needs, research priorities, and the potential for One Health to generate increasingly deep interdisciplinary and transdisciplinary insights into the socioecological, health-related interconnections between humans, other animals, plants, and the environment at large. In section 7, we present a One Health case study on food systems. In section 8, we build on the marked political traction that One Health has achieved, by proposing three avenues for One Health operationalisation, implementation, and institution——alisation and by explicating the role that One Health can play in realising equitable, sustainable, and healthy socioecological systems. Embedded throughout this

Panel 2: An operational One Health ethos

The One Health ethos put forward by this Commission builds on existing One Health principles and frameworks[46,49,68,69] and reflects values that are inherent to EcoHealth and Planetary Health.[70,71] This ethos is also aligned with the definition of One Health put forth by the One Health High-Level Expert Panel, which this Commission endorses. This ethos also emphasises a sustainable and optimal balance between the health of people, animals, and ecosystems, with appreciation for the health interdependencies between humans, domesticated and wild animals, plants, and the environment at large, as well as the need for collaboration across disciplines and local, national, regional, and global sectors. Similarly, this ethos is aligned with the One Health principles outlined by the One Health High-Level Expert Panel, which include equity, sociopolitical parity, socioecological equilibrium, stewardship, transdisciplinarity, and multisectoral collaboration.[72]

Holism and systems thinking

One Health assumes a holistic perspective that appreciates the complexity of socioecological systems, including the dynamics of uncertainty, nonlinearity, mutability, interdependence, and varied spatiotemporal scales. Insight is generated through an understanding of systemic interconnections and, therein, tipping points, feedback loops, and resilience. In short, the whole is more than the sum of its parts and each part is best understood in terms of its inter-relations within the whole.[73]

Epistemological pluralism

Epistemological pluralism appreciates that there are multiple ways of knowing, which together enable a more comprehensive understanding of the complexities of the socioecological system. Epistemological pluralism can be realised through transdisciplinarity. Transdisciplinarity entails an interdisciplinary integration and synthesis of knowledge, perspectives, and methods from multiple disciplines,[74] as well as a trustful, participatory, transparent, and inclusive processes of knowledge exchange and integration that transcends disciplinary boundaries and brings together diverse knowledge systems in equitable ways, resulting in the emergence of novel, holistic perspectives.[75] Operationally, this process translates into multisectoral, interlevel, and multilateral collaboration, as well as participatory processes and partnerships that facilitate the integration of scientific, Indigenous, and situated knowledges, with recognition that these and other forms of knowledge are not mutually exclusive.

Equity and egalitarianism

The principle of equity that underpins One Health demands an active creation of the conditions under which all humans and other animals, plants, and the ecosystem can thrive, now and in the future. The reach is thus planetary (including the entirety of the ecosystem), global (including all humans), and intergenerational (including all planetary constituents of the present and future). Ecological and social justice are imperatives. Egalitarianism demands political, economic, and social equality, and, likewise, an equal distribution of agency. Core tenets include participation, inclusivity, solidarity, trust, and transparency, all of which challenge and have the potential to reconfigure dynamics of privilege and vulnerability.[76]

Stewardship and sustainability

Stewardship couples the right to benefit from the ecological world with the socioecological responsibility to care for and sustain it, and the knowledge and freedom of choice that is possessed today with the power and duty to act in service to tomorrow. One Health stewardship cultivates leadership and participation for equitable, sustainable, and healthy socioecological systems.[77] Sustainability can be understood as the state of balance between economic, social, and environmental interests that is necessary to enable humans, other animals, plants, and the wider ecosystem to coexist and thrive over time.

Commission is a collection of interdisciplinary, transdisciplinary, socioecologically oriented, equity-centred, and inclusivity-centred principles that can guide the equity and sustainability transitions that are at the heart of the One Health paradigm shift (figure 1, panel 2, figure 2). When referring to the constituents of the socioecological system and the domains across which One Health advances health, we are referring to humans, other animals (both terrestrial and aquatic as well as domesticated and wild), plants, other biological kingdoms (including fungi), and all other biotic and abiotic elements that make up the environment at large (including soil, water, and air). We include these elaborations in parentheses here and intend for them to be implied throughout the remainder of the Commission, albeit without reiteration.

1. Socioecological interconnection: the foundation of One Health

1.1 A socioecological systems perspective

Traditionally, One Health scholarship has focused on the prevention and control of zoonotic diseases at the

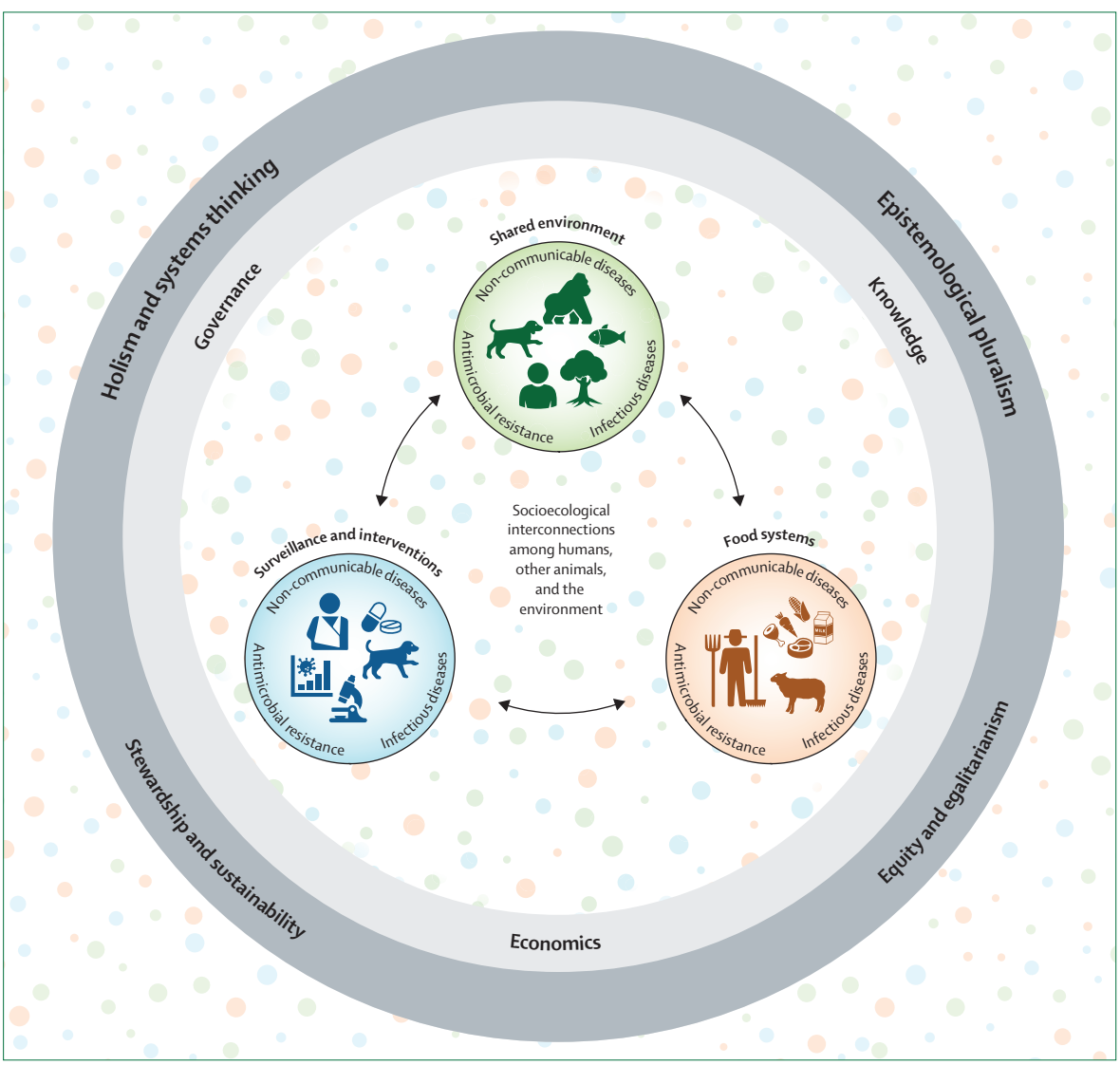

Figure 2: **One Health wheel**

One Health has classically been illustrated as three intersecting circles representing humans, animals, and the environment, but this has been critiqued as reinforcing a western-centric ontology and a heavily biomedical epistemology that risks disregarding the social, cultural, historical, and political contexts of health,[78] as well as Indigenous and situated knowledges.[79] The classic One Health illustration is stymied by a disproportionately heavy emphasis on the human–animal interface and zoonotic diseases, which entrenches the false dichotomy of humans and other animals. Instead, we present an illustration that conveys the fundamental interconnectedness of One Health and depicts our approach to anchoring socioecological health and sustainability in the interconnectedness of life, without boundaries between humans, other animals, and the environment. The illustration also depicts three avenues for One Health operationalisation, implementation, and institutionalisation (governance, economics, and knowledge), as well as, in the outermost layer, the principles encompassed by our proposed One Health ethos.

human–animal interface, collaboration between the human and veterinary health systems, and, more recently, AMR.[80–83] The environment has conventionally received insufficient attention.[81,84–87] In this Commission, we appreciate the centrality of the environment and recognise socioecological interconnection as the foundation of One Health and as advancing a socioecological perspective on the health interdependencies among humans, other animals, plants, and the environment at large. Of central concern is the triple planetary crisis of climate change, pollution, and biodiversity loss, and the threats that it poses to sustainability and health.[88]

Scientifically, this perspective is informed by an interdisciplinary and transdisciplinary field of socioecological systems research that spans the natural sciences, social sciences, and humanities. This research examines the complex inter-relations between and among the ecological systems of the biosphere and the social, cultural, political, and economic systems of the human-constructed world, helping us to understand their convergence and the dynamics that result.[89] Among the dynamics inherent to socioecological systems (ie, the qualities that characterise socioecological inter-relations) are fluctuation, uncertainty, non-linearity, and interdependence. In addition, socioecological systems are characterised by varied and intersecting spatiotemporal scales, from the microspatial scale of individuals and communities to the macrospatial scale of global and planetary systems, and from the intragenerational timescales to the intergenerational and evolutionary timescales. A socioecological systems perspective is therefore holistic and grounded in an understanding of systemic interconnections and the potential of changes within any facet of the system and at any scale to affect and catalyse effects of importance for other facets, at other scales, and for the system as a whole.[90] A socioecological systems perspective also generates insight into resilience, which can be understood as the adaptive capacity of an ecosystem to maintain crucial functions amid transformation.[14] As

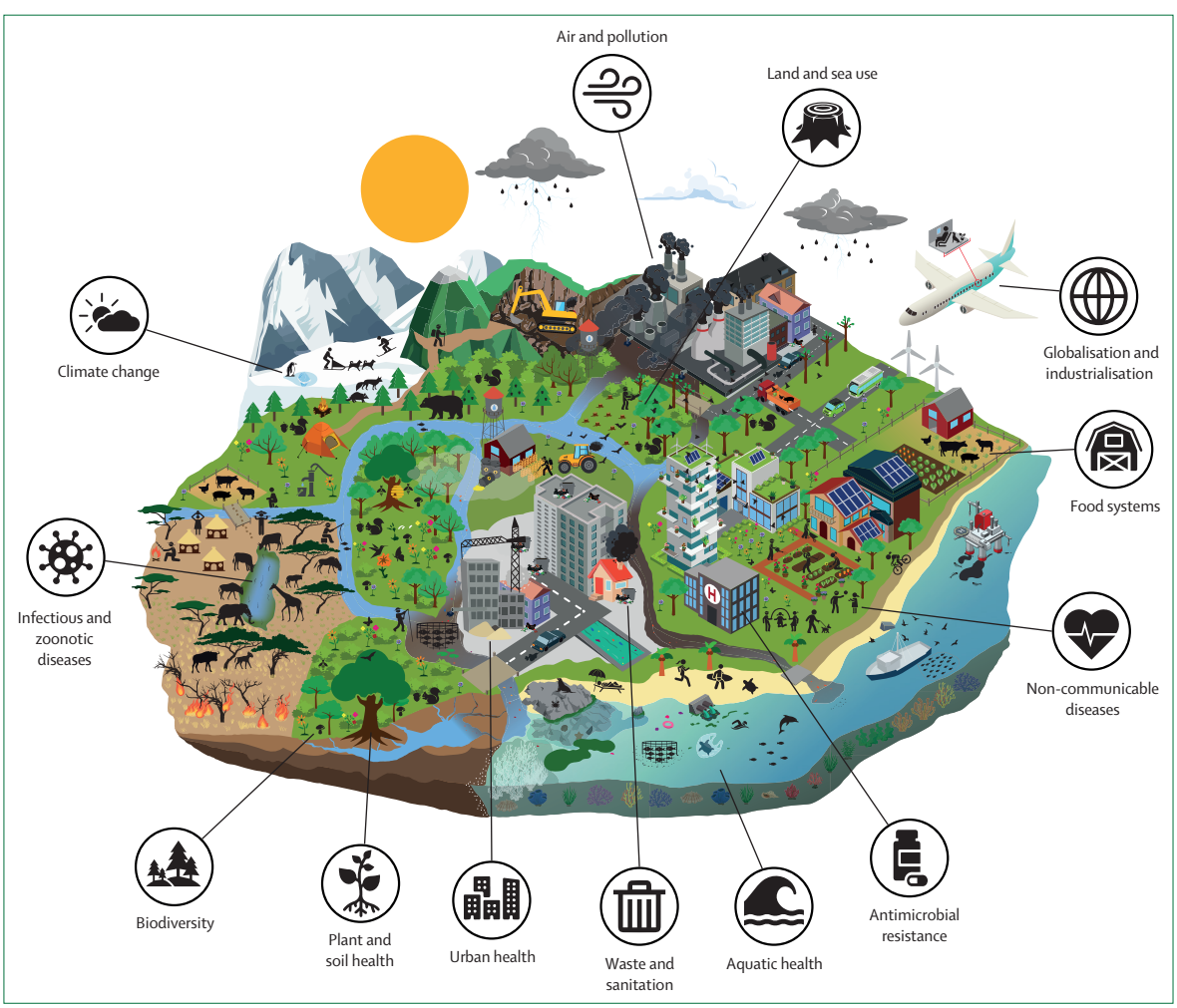

Figure 3: **Mapping the socioecological system**
For a detailed explanation of each icon included in this figure please see the appendix (pp 27–28).

such, a socioecological systems perspective enables full expression of the principles outlined in our One Health ethos (panel 2). This perspective also sheds light on the significance of the environment, and therein plants, soil, fungi, water, air, wildlife, biodiversity, and climate (figure 3).

1.2 Plants, soil, and fungi

The interconnections and health interdependencies among plants, soil, fungi, and animals, including humans, are abundant. Through converting sunlight, water, and carbon dioxide to energy and releasing oxygen (ie, photosynthesis), plants serve essential atmospheric functions and are the fundament of the ecological food chain, as well as a vital source of habitat, renewable and biodegradable fibres, medicines and therapeutics, and cultural and spiritual significance.[91,92] Moreover, plants, the pollens and nectars that they produce, and the products that are derived from them supply more than 80% of the food consumed by humans and provide nutrition for domestic and wild animals, including insects.[85] As such, plants play a crucial role in the food systems and livelihoods on which the health and wellbeing of humans and other animals depend.

The health of plants is directly and indirectly affected by humans and other animals. Plants face several health threats that can lead to compromised yields, quality, and nutritional value, as well as other consequences for health throughout the socioecological system. These threats and consequences include plant pathogens that cause the loss of crops, potentially jeopardising livelihoods and risking malnutrition and famine; mycotoxins, which are naturally produced by moulds that grow on crops and food products, but can cause severe disease if ingested by humans or other animals; pathogens that colonise plants and use them as vectors between animal hosts, risking foodborne disease; and misuse of pesticides and other pollutants, including perfluoroalkyl and polyfluoroalkyl substances (PFAS; ie, forever chemicals). Use of PFAS risks exposing humans and other animals to dangerous residues, and disrupting the diversity and balance of bacteria, fungi, and their predators in the soil, which can have implications for the plant microbiome, plant resilience, and the gut microbiome and immune response of humans and other animals who consume plants and plant products.[85,86,92–96]

Healthy plants, and hence, healthy humans, animals, and socioecological systems, are sustained by healthy soil. Soil cycles microbials between the environment on the one hand and plants and animals on the other, underscoring its crucial role in achieving and maintaining a diverse and balanced, interconnected microbiome.[86] Diversity and balance among gut microbiota are important for the development and functioning of the immune system, and thus for health among humans and other animals.[97] A growing body of research is generating insight into the inter-relationships between the soil and gut microbiome.[98,99] Several additional interdependencies between the health of soil, plants, humans, and other animals are also important, including that the nutritional content of plant-based foods and feed is largely determined by the fertility and nutrient balance of the soil; that soil distributes rain water and filters out contaminants, hence serving crucial water supply and water quality functions; that soil sequesters carbon, thereby mitigating climate change; and that antibiotics and other medicines are derived from soil.[100–102] Threats to the health of soil and the consequences for plants, humans, and other animals include deposits of PFAS, plastics, and heavy metals. The deposit of heavy metals is largely a result of agricultural and mining practices, constitutes an exposure health risk for humans and other animals, and potentially promotes AMR.[103] Desertification also threatens plants and increases the health risks posed by airborne dust, including exposure to soilborne pathogens,[100,104] which can ultimately lead to the destruction of the ecosystem at large.

Fungi also play a crucial role in the socioecological system. Although greater attention is conventionally directed to the risks posed by fungi, fungi serve many essential functions. Some fungi are decomposers that are central to cycling nutrients in the soil, sequestering carbon, and degrading environmental pollutants. Some fungi are also nutrient-rich food sources for humans and other animals, possess medicinal properties, serve natural biofertilising and pest-control functions, and can be used as a sustainable alternative to unsustainable plastic, synthetic, and other materials. Together with plants and soil, fungi are threatened by deforestation, other forms of land-use change, and soil degradation.[105,106]

1.3 Water

From the freshwater supplies that enable food production, to the wetland and marine ecosystems that regulate climate, maintain the global hydrological cycle, and support biodiversity, the socioecological importance of water cannot be overemphasised, nor can the gravity of the threats to health and sustainability posed by escalating water crises.

More than half of the global population is affected by freshwater scarcity, which jeopardises the irrigation systems that food and feed production depend on, risks infectious disease outbreaks when crops are grown with contaminated water, facilitates the transmission of infectious diseases due to insufficient hygiene, and drives conflict over natural resources and displacement, all of which exacerbate poverty, food insecurity, and malnutrition.[107–109] These burdens are disproportionately borne by women and girls, who are estimated to spend more than 200 million h daily collecting water,[110] and by the 700 children younger than 5 years who die each day from diarrhoeal diseases associated with contaminated water and food and inadequate hygiene and sanitation.[111]

Severe inequities in water access exist globally, including between high-income and low-income urban locales, between industrial agriculture and small-scale subsistence farms, and between men and women.

Water scarcity and its effects on global health, food security, grain production, and gross domestic product (GDP) are expected to continue to rise under the increasing pressure of climate change and unsustainable human demand, with a continued disproportionate effect on marginalised populations and those with low income, thus deepening inequities and impeding progress towards the 2030 Sustainable Development Agenda.[108,112] Additionally, by 2050, growing populations in flood-prone regions, indiscriminate deforestation, wetland mismanagement, rising sea levels, and climate change are anticipated to subject 2 billion people to flood disasters and their impacts, including vector-borne and waterborne diseases, destruction of infrastructure and property, productivity and investment losses, and loss of crops, livestock, and aquaculture.[113]

Oceans and the crucial functions that they serve within the socioecological system are also at stake. Oceans are among our richest sources of biodiversity, but human-driven extinctions and climate change are reducing biodiversity, and both biodiversity loss and climate change are associated with increases in invasive species.[114] Moreover, unsustainable exploitation of marine ecosystems jeopardises marine life and generates direct health risks for humans and other animals. This exploitation includes destructive harvesting practices and intense fishing, as well as pollution from oil spills, agricultural and urban runoff, and point sources (eg, factories and sewage treatment plants), which contaminate the sea with antimicrobials and other pharmaceuticals, plastics, persistent organic compounds that bioaccumulate in marine life, and toxic, heavy metal, and radioactive wastes.[115] The associated health threats include contaminated seafood and seafood-borne infectious diseases; algal bloom toxins that risk mortality among fish, other aquatic life, and humans; plastics-induced animal injuries and deaths; and chemical pollutants. Indirect threats to health also arise when coastal economies and cultures collapse[114,115] and when marine-derived therapies (which research suggests could satisfy some of our most pressing treatment needs for cancer, inflammation, infectious diseases, and other health challenges), aquatic food supplies, and the psychosocial health benefits and sociocultural value associated with oceans and coastal environments become at risk.[116–118]

1.4 Air

From a socioecological perspective, air is another abiotic element of One Health significance. Due to human-induced and human-accelerated environmental degradation and air pollution, 99% of the human population breathes suboptimal and health-threatening outdoor air.[119] Other animals and plants are exposed as well. Exposure to polluted air is inimical to cardiorespiratory health for humans and other animals, and to the metabolic function of plant species. An estimated 4·2 million premature human deaths were attributed to outdoor air pollution in 2015, the majority of which occurred in LMICs.[120] For plants, air pollution affects net carbon fixation, potentially catalysing a

Panel 3: Climate change and One Health

Climate change, driven by the industrial revolution, which advanced human civilisation at the cost of an unprecedented rise in the average global temperature, is among the foremost global health and sustainability challenges of the 21st century.[127–129] Despite political and scientific will,[130–132] current indicators suggest that contemporary decarbonisation pledges will fall far short of adequately mitigating climate change and the serious global health and sustainability challenges it generates.[129]

The drivers of climate change prominently include the greenhouse gas emissions that result from the burning of fossil fuels and related industrial processes; energy intensity associated with current consumption and production trends; and agriculture, deforestation, and other land use changes.[133,134] Furthermore, climate change, pollution, and biodiversity loss compound and exacerbate one another, constituting what is known as a triple planetary crisis.[88] For example, rising temperatures can enhance the toxicity of contaminants, thus increasing the burden of disease and other negative effects associated with air, water, and soil pollution,[135] and air pollutants—in particular the so-called short-lived climate pollutants, including methane, black carbon (also known as soot and part of fine particulate matter), and some hydrofluorocarbons—have considerable global warming potential.[126] Climate change affects pathogens and vectors, which in turn affect infectious disease epidemiology.[136–138] Warm climates promote the survival and fast lifecycle completion of vectors, such as mosquitoes and ticks,[127,139] and an increase in foodborne parasitic infections.[140] Climate change might also alter the geographical range and incubation period of such vectors,[141] thus increasing the risk of associated diseases. Recurrent airway obstruction has also been shown to worsen in horses with high temperature,[142] and climate change has been associated with an increase in the global prevalence of some chronic diseases, such as cardiovascular diseases and asthma,[143] as well as nephropathies associated with heat stress, which are occurring at epidemic rates in increasingly hot regions of the world.[144,145] Climate change has also been suggested to exacerbate antimicrobial resistance through several mechanisms, including the accumulation of pollutants that cause antimicrobial resistance, particularly in soils and water, caused by runoff from increased storms and rainfall.[146]

Global warming from climate change also detrimentally affects the health of livestock, by inducing heat and oxidative stress, metabolic disorders, and immune suppression, which lead to increased antimicrobial use in farm animals.[147] In some semiarid lands where livelihoods and dietary sustenance depend on livestock, droughts are responsible for mass livestock death.[148] Droughts exacerbate the crisis of water scarcity and can lead to conflict when nomadic pastoralists encroach on new lands in search of pasture.[149] Additionally, some invasive species have broad thermal tolerance. In Fiji, for example, thermoresistant invasive bee species differentially pollinate invasive plants, thus disrupting the native ecosystem balance by promoting the proliferation of harmful plant species.[150]

Investment in climate-resilient health systems is therefore urgently needed,[128] including the integration and dynamic use of climate data in epidemiological One Health surveillance systems for infectious disease outbreaks that affect humans and other animals.[136,141] Importantly, the deleterious effects of both climate change and climate change mitigation interventions disproportionately impact low-income countries, particularly economically,[151] thus reinforcing the centrality of global and intergenerational equity considerations and climate justice.

harmful cycle that threatens the competitive balance among plant species, negatively altering plant biodiversity, and potentially reducing the economic yield of agroecosystems.[121] Air pollution can potentially also exacerbate AMR by increasing the frequency of respiratory infections (and thus the consumption of antimicrobials by humans and other animals) and by promoting the concentration of antimicrobial-resistant genes in the air.[122]

Indoor household air pollution is also of concern, both as a contributor to outdoor air pollution and due to its direct impact on health, with household pollution from solid fuels having caused approximately 2·8 million human deaths and 85·6 million disability-adjusted life years (DALYs) in 2015.[120] Nearly all deaths due to household air pollution occur in LMICs.[123] Although the impact of indoor and outdoor air pollution on animals is poorly studied, air pollution in urban settings has been suggested to increase the frequency of recurrent airway obstruction in horses.[124] In one study, household particulate matter with a diameter of less than 2·5 µm was found to be significantly higher in cats with respiratory disease than in control cats without respiratory disease.[125] Interlinked with air pollution[126] is climate change (panel 3).

1.5 Wildlife and biodiversity

Wildlife (ie, wild animals and vegetation) is crucial for healthy ecosystems and provides essential ecosystem services. However, within conventional One Health scholarship, wildlife species (and particularly wild animals) have predominantly been reduced to their role as the origin of emerging infectious diseases that threaten humans. Bats, for instance, are often vilified for harbouring pathogens of high risk for humans and other animals, but they also play an essential role in supporting healthy ecosystems as seed dispersers, pollinators, and insect population controllers. The abundance, genetic diversity, and geographical spread of bats as the second largest group of mammals after rodents is of great socioecological significance.[152,153]

The numerous ways wildlife species matter should be appreciated more fully, especially in the advent of multiple changes that are threatening wildlife across ecosystems around the world. Of particular importance is biodiversity, which refers to the variability that exists within and between all living organisms. This biological variability is the foundation for the diverse biotic and abiotic interactions that yield and sustain functioning ecosystems and ecosystem services, such as oxygen production during photosynthesis, purification of air and water, pollination and pest control, medicine for humans and other animals, and sociocultural and psychosocial benefits, as described in more detail in section 6.[154] The importance of biodiversity is also seen in the interaction among microorganisms and between microorganisms, humans, other species, and the environment, with respect to the interconnected microbiome and inter-relationships between the soil and gut microbiota,[86,98,99] as discussed in section 1.2.

Biodiversity has implications for the emergence and spread of infectious diseases, with growing evidence that biodiversity loss often increases the risk of disease transmission. The relationship between biodiversity and disease risk varies across pathogens, hosts, vectors, transmission routes, and scales (ie, genetic, microbial, organismal, community, habitat, and geographical). Some of the mechanisms through which biodiversity loss can increase disease risk include altered gene frequencies among pathogens or host populations and accompanying changes in pathogen virulence or host resistance; altered composition of microbial communities in the environment or hosts and accompanying changes in pathogen exposure, pathogen virulence, or host immune response; and altered abundance, distribution, diversity, composition, and geographical range of vectors and hosts, and accompanying changes in pathogen prevalence, host competence (ie, probability of infection and subsequent transmission of the microorganism), or contact rates between competent hosts, vectors, pathogens, and humans.[155–157]

Given the increasingly understood relationship between biodiversity and infectious diseases, as well as the importance of biodiversity for healthy and sustainable socioecological systems at large, the current, rapid decline of biodiversity is of grave concern. Since the 1870s, the live coral cover on coral reefs has reduced by approximately half, 32 million hectares of forests in the tropics were lost between 2010 and 2015, and this past century has seen a fall of at least 20% in the average abundance of native species in most major terrestrial biomes, as well as declining vertebrate and insect populations.[158] Approximately 1 million species of animals and plants are currently estimated to face extinction, and the diversity of varieties and breeds of domesticated animals and plants is also declining, with consequences for the resilience of food systems.[158]

Foremost among the drivers of biodiversity loss are changes to the use of land and the sea, as well as overexploitation of the animals and plants that they contain. Agricultural expansion constitutes the most extensive land-use change, with agriculture claiming almost half of the habitable land globally.[159] This expansion has entailed mass conversion of forests, wetlands, and grasslands, as well as widespread human encroachment on what was primarily wildlife habitat. Agricultural expansion has been coupled with unsustainable harvesting practices (ie, overexploitative logging, hunting, and fishing), a doubling of urban areas, and extensive infrastructure developments to support the growing human population and consumption. In addition to severe consequences for biodiversity, these activities have increased the proximity and contact that humans and domesticated animals have with wildlife,

which has increased the risk of pathogen spillover.[160–162] Additional key and interlinked, anthropogenic drivers of biodiversity loss include climate change, pollution, and invasive alien species.

Although the drivers of biodiversity loss and the threats posed to health and sustainability throughout the socioecological system have for many years been well understood,[6] the prevailing global strategy, including in the context of pandemics, has been largely reactive. Likewise, despite established knowledge about the essential role of environment within the socioecological system, human-driven degradation continues to threaten the plants, soil, water, and air that sustain all life. The consequences are grave and the evidence is clear: to achieve the biodiversity conservation and ecological restoration that a healthy and sustainable future presuppose, the world must embrace transformative change and "a fundamental, system-wide reorganisation across technological, economic and social factors, including paradigms, goals and values".[158] One Health, including the socioecological orientation and principles of holism and systems thinking, epistemological pluralism, equity and egalitarianism, and stewardship and sustainability embedded throughout this section of the Commission (panel 2), has an important role to play in this transformation through advancing our understanding of socioecological interconnections. An integrated, interdisciplinary, transdisciplinary, and multisectoral approach should be taken to mitigating the current socioecological crises faced and supporting healthy and sustainable socioecological inter-relations.

2. Before and beyond disease: One Health surveillance

2.1 The need for One Health surveillance

Surveillance, in the context of health, traditionally entails continuous and systematic collection, analysis, interpretation, and dissemination of health-relevant data to inform the development, implementation, and assessment of interventions and policies.[163,164] The International Health Regulations established by WHO in 1969 required reporting of cholera, yellow fever, and plague. The revised International Health Regulations of 2005, which followed the 2002–04 severe acute respiratory syndrome outbreak, provide criteria to assist in deciding whether an event poses a substantial enough global threat to be designated a public health emergency of international concern.[165] The WOAH has also had a system in place for monitoring disease outbreaks in mostly domesticated animals and livestock since 1924 and, in 2005, established the World Animal Health Information System, a database for reporting and disseminating information about animal health globally.[166,167] In 1998, the WHO Africa Regional Office initiated the Integrated Disease Surveillance and Response strategy for strengthening disease surveillance in sub-Saharan Africa.[168] The current Integrated Disease Surveillance and Response technical guidelines have been in operation since 2010, with the primary goals of integrating multiple pre-existing vertical surveillance systems and linking surveillance data to public health action with a focus on human health.[169,170]

Some health concerns, such as emerging zoonoses, AMR, and contaminants in food, soil, water, and air, require a multisectoral approach to surveillance, sometimes referred to as integrated surveillance, collaborative surveillance, or One Health surveillance. Although different definitions circulate, three fundamental features of One Health surveillance are the integration or triangulation of data from different sources (ie, human, animal, and environmental), the necessity of multisectoral collaboration, and the application of a systems-based approach.[171–173]

The need to implement a One Health approach to surveillance for health concerns at the human–animal–environment interface is widely recognised.[13,174–176] One Health surveillance is essential for timely and effective detection of emerging and re-emerging infectious agents. The sizeable burden of infectious diseases among humans and animals underscores the importance of well coordinated, interdisciplinary, transdisciplinary, multisectoral, and multilevel systems for collecting, analysing, and modelling data (empowered by big data and artificial intelligence), and for producing information to guide interventions.[177,178] One Health surveillance systems can also report on and exchange information about antimicrobial-resistant infectious agents detected in various species and the environment. Averting biodiversity loss on account of invasive alien species, as well as preventing and mitigating the environmental impact of toxic pollutants on plants, animals, and humans, can be achieved via One Health surveillance.[179]

The biological vulnerabilities shared by humans and other animals, including with regard to NCDs (as discussed in section 5), point to the opportunity to promote health among all species through a One Health approach to surveillance. For example, a study based on data from a companion animal surveillance network showed considerable similarities between humans and companion dogs in the occurrence of comorbidities related to common chronic conditions, including obesity and diabetes, as well as similarities in age-related changes in disease risk.[180]

Within food systems, applying a One Health approach in periodic reviews of production, distribution, and consumption, and accounting for seasonal, cultural, and economic variations and dynamics, can improve efficiency and health outcomes. Surveillance can then target crucial interfaces between humans, animals, plants, and the wider environment, including those that are context-specific or easily overlooked by existing surveillance systems. For example, food safety surveillance might focus on identifying points in food

systems where risks exist for the emergence, spread, and transmission of pathogens, thereby contributing to early warning and response.

As One Health surveillance continues to evolve, important opportunities might emerge to monitor a wide range of human-mediated changes to the socioecological system and how these changes drive the emergence, spillover, and spread of infectious agents.[160,181–185] One Health surveillance should therefore, in the future, aim to monitor not only threats, but also the wider determinants of healthy and sustainable systems.

2.2 The current state of One Health surveillance

During the COVID-19 pandemic, One Health surveillance focusing on infectious diseases at the human–animal–environment interface received increasing attention. However, the current state of One Health surveillance globally is insufficiently documented. A systematic review published in 2020 identified 41 articles describing national One Health surveillance systems, mostly in Europe, but also a few in LMICs.[186] Almost half of these surveillance systems involved multisectoral collaboration in varying degrees and at various stages of the surveillance process, but predominantly at the operational level, for the implementation of surveillance activities, including data collection and analysis. The coordination of surveillance was most often led by the public health sector and the primary aim of these surveillance systems was to improve human health; improvements to the health of animals and the environment remained secondary or were not among the considered outcomes. The identified systems mostly targeted the prevention of foodborne and vector-borne zoonoses, as well as AMR, with only two publications focusing on non-communicable hazards, such as environmental contaminants.[186] Given that very few One Health surveillance systems are reported in peer-reviewed literature, this systematic review, albeit generating important insights into the characteristics of some One Health surveillance systems, probably captured only a small proportion of existing systems.

Another systematic review from 2020 indicated that existing One Health surveillance systems were diverse in their objectives, structure, and governance, ranging from poor multisectoral collaboration for narrow purposes to complex programmes that involve multiple sectors and many points of integration.[164] Good examples of integrated One Health surveillance systems are those for AMR, which often integrate data on resistance to diverse drugs in bacterial species, humans, and animal species and products with data regarding antimicrobial usage in different sectors.[187] These AMR surveillance systems necessitate not only collaborations between multiple institutions and sectors, but also the harmonisation of data collection, complex analysis, and interpretation processes. These systems also necessitate long-term programmes to inform decision making, including policy changes, such as restrictions on the use of some antimicrobials in some sectors (eg, the animal health sector) to protect their efficacy when used in others (eg, the human health sector).[188] Large-scale, event-based surveillance systems that integrate human, animal, and environmental data also exist and are continuously being improved.[189] The degree to which the One Health approach is implemented within these large information systems has not yet been evaluated.

One Health surveillance that includes NCDs is, along with other barriers, hindered by the scarcity of relevant data and an underdeveloped conceptualisation, such as with regard to the links between food systems, obesity, and NCDs. In LMICs, systematic NCD data collection among humans (eg, cancer registries and risk factor surveys) is substantially less established than in HICs.[190] Similarly, NCD registries for companion animals exist only on a small scale.[191–193] NCD surveillance of wildlife, livestock, and fisheries (eg, for traces of pharmaceuticals and other contaminants) does not receive sufficient attention.[194] Although much still needs to be done, investing in multispecies, interdisciplinary, trans-disciplinary, and multisectoral NCD surveillance systems has vast potential. For example, both humans and livestock in Costa Rica, Nigeria, and several other countries are exposed to mycotoxins through ingestion of contaminated plant foods or feed.[195,196] Exposure is associated with various NCDs, such as liver cancer in humans and reduced reproductive capacities in livestock. A One Health approach to surveillance, including surveillance for mycotoxin-associated health outcomes in humans and livestock and environmental monitoring for mycotoxins in food products, might help prevent and manage this problem.[195]

In the previous two decades, large increases in emerging plant diseases and the consequences for crop production and food security have underscored the importance of surveillance for plant health and the need to strengthen existing plant disease surveillance systems.[197] Although little overlap exists between infectious agents that cause diseases in plants (phytopathogens) and those that cause diseases in humans and other animals, some chemicals and other pollutants can cause harm to all species.[198,199] Furthermore, concern is increasing that phytopathogenic fungi, bacteria, and viruses might have a stronger impact than previously thought on the health of humans and other animals.[200,201] Evidence of the human-mediated spread of phytopathogens on both local and global scales is overwhelming[202] and brings opportunities for surveillance collaborations across the human, animal, soil, water, and plant sectors, particularly given shared infrastructure and data needs.

Although not novel, the use of wastewater surveillance (ie, wastewater-based epidemiology) has become an integral part of One Health surveillance programmes, particularly during the COVID-19 pandemic.[203]

Researchers have proposed that One Health surveillance programmes can be designed by identifying key environmental conditions in various countries or regions and applying the principle of one sample, many analyses. This principle has been described as involving sample collection informed by the environmental setting (natural, rural, urban, or industrialised), followed by a testing regimen informed by the known health risks in and catchment area size of each setting.[204]

2.3 The performance and added value of One Health surveillance

Although the need for One Health surveillance is widely recognised, few studies have formally evaluated its added value compared with unisectoral surveillance approaches. One main challenge has been establishing direct links between the information produced by One Health surveillance systems and improved decision making for effective disease prevention and control. Nevertheless, the One Health approach provides opportunities for coordinated local, national, regional, and global disease prevention. Primordial and primary prevention, also known as upstream and midstream prevention, or collectively as deep prevention, focuses on preventing the infection or other pathological process from occurring in the first place. Secondary and tertiary prevention, also known as downstream prevention, focuses on preventing symptoms and severe disease or death.[205–207] Once the use of the One Health approach for both deep and downstream prevention is recognised for various populations, its added value becomes more evident, particularly in complex programmes that integrate multiple sources of information, such as integrated surveillance systems for AMR and antimicrobial use.[208,209] Importantly, some studies do report improved surveillance performance. With regard to zoonotic diseases in Guatemala, the sensitivity and representativeness of a surveillance system increased when data from multiple sources were integrated.[210] In one study from Australia, supplementing routinely collected climate data with mosquito surveillance data increased the sensitivity for the prediction of Ross River virus epidemics from 64% to 90%.[211] Additionally, in Brazil, educating health agents and communities about One Health surveillance and merging previously separate zoonoses surveillance groups strongly improved the reporting of zoonoses.[212]

One Health surveillance can also generate cost savings, both through resource sharing and through the early detection of outbreaks (including the early detection of pathogens in environmental or animal reservoirs[68]), thereby enabling preventive interventions before pathogen spillover. From a public health perspective, the generally accepted assumption is that the earlier changes are detected in the presence or biology of insect and other vectors and reservoir hosts, or the earlier that a pathogen is detected in animals, food chains, or the environment, and the better the communication is between the surveillance systems in different sectors, the more likely spillover to human populations is to be prevented or rapidly contained (or both). Consequently, larger outbreaks might be avoided and economic, social, and human costs can be minimised.[213] Preventing pathogen spillover to other species is also important, as pathogen spillover has consequences for biodiversity and in the agricultural and other sectors. From a socioecological perspective, One Health surveillance might also monitor a wide range of human-mediated changes to the socioecological system and how these anthropogenic changes drive the emergence, spillover, and spread of infectious agents,[160,181–184] with attention to the different pathways through which pathogens spread and to the effects throughout the socioecological system (figure 4).

The capacity of One Health surveillance to improve early detection of pathogens before they reach the human population has been documented in several contexts. Surveillance systems integrating data on infectious agents that circulate in vectors (eg, mosquitoes), reservoir hosts (eg, birds), or sentinel species (eg, horses) have been shown to be effective in the early detection of West Nile virus and Crimean–Congo haemorrhagic fever.[218–220] In Bolivia, coordination among workers at a wildlife sanctuary, researchers, and the Ministry of Health enabled the early detection of yellow fever in wild monkeys. This early detection mobilised a rapid multisectoral response, including human vaccination and community outreach, with no human cases reported.[221] In Brazil, the integration of non-human primate health monitoring in yellow fever outbreak prevention is well established and informs human vaccination programmes.[222] Although a reduction in yellow fever outbreak size was documented in Brazil, the associated cost savings due to early detection stemming from One Health surveillance are not known.

Evidence regarding the value of One Health surveillance, including its costs and benefits, is scarce, due to a paucity of studies on the topic and challenges in study design. One cost–benefit study calculated direct financial savings of more than €160 000 from 2009 to 2015 in one Italian region when conducting integrated surveillance for West Nile virus in mosquitos, wild birds, horses, and humans, as compared with surveillance in humans only.[223] Conversely, another study on the economics of *Campylobacter* spp surveillance in Switzerland found an increase in costs associated with mitigation activities for 5 years following the implementation of surveillance activities in the poultry sector, with no disease burden reduction among humans.[224] Studies assessing the economic value of One Health surveillance have largely focused on health improvement in human populations. Increased understanding is needed in terms of the costs and benefits of this approach, especially with regard to the

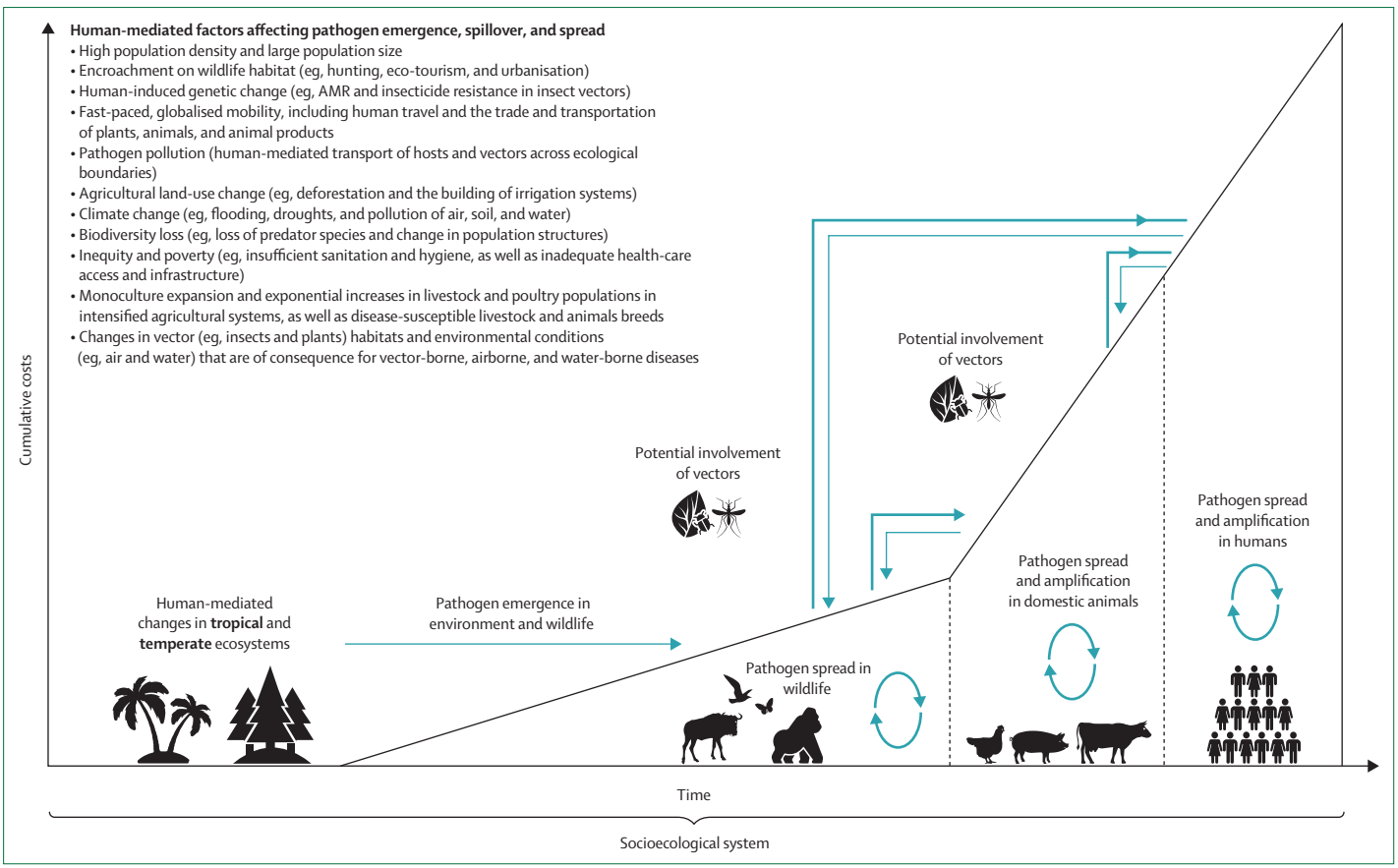

Figure 4: **An example of pathogen emergence in the environment and wildlife, spillover, and spread throughout the socioecological system**
The more extensively infections spread throughout the socioecological system, the higher the cumulative societal cost.[213] A One Health approach to early detection and intervention is indispensable for preventing the wide spread of infections.[214] As One Health surveillance continues to evolve, important opportunities might arise to monitor a wide range of human-mediated changes to the socioecological system and how these anthropogenic drivers pose risks for infectious disease emergence, pathogen spillover, and spread.[160,181-184] Pathogens can emerge in wildlife and transmit to humans through direct contact or insect vectors. Other infectious diseases can spread from wildlife to domestic animals, who then transmit to humans through direct contact or insect vectors.[215] Although public health concerns commonly focus on the transmission of pathogens from animals to humans (thick arrows), reverse transmission from humans to animals can also occur (thin arrows).[216] Adapted and expanded from Karesh and colleagues, the World Bank, and the National Research Council Committee on Achieving Sustainable Global Capacity for Surveillance and Response to Emerging Diseases of Zoonotic Origin.[51,214,217]

health of animal populations and the preservation of ecosystems. Intrinsically, the aim of One Health surveillance is to reduce the risk of pathogen emergence, spillover, and spread in ways that yield the highest overall co-benefits with, and the least negative consequences for, other health and sustainability objectives.[225,226] As illustrated throughout this section, the co-benefits and trade-offs of implementing One Health surveillance vary across contexts, geography, and time scales, which underscores the need for consensus around priorities that is guided by the principles outlined in our One Health ethos (panel 2).

Finally, applying a One Health approach to surveillance also leads to important long-term and potentially intangible benefits, such as the growth of social and intellectual capacity[224] and increased sustainability and resilience of national or regional mitigation systems due to enhanced multisectoral collaboration and the existence of multisectoral networks of professionals.[172] Evaluations of the added value of One Health surveillance should therefore look beyond monetary benefits or averted human diseases, taking a whole-of-society and socioecological perspective that accounts for and values wider societal and socioecological costs and benefits (see section 6.5 for an overview of economic frameworks that might be appropriate for evaluating the One Health approach). Furthermore, to guarantee more tangible added value, establishing clear steps for developing and operationalising One Health surveillance systems is crucial, including clarity around required roles and responsibilities, as well as expertise and capacities. The OHHLEP has suggested six steps to overcome barriers and to optimise an integrated One Health surveillance system: develop the surveillance system scope, identify the data requirements, develop the system design, develop the governance of the system, develop integrated protocols, and develop a joint implementation road map.[227]

2.4 Barriers to and facilitators of One Health surveillance

At both the systems and operational levels, barriers to and facilitators of One Health surveillance can be recognised. Barriers include the dearth of investigations into the value of One Health surveillance, from which follows an insufficient evidence base, little awareness of the importance of One Health surveillance, and the absence of a designated One Health surveillance workforce and operational capacity. Barriers also include poor adoption of the One Health approach to diagnostics (including shared laboratories as discussed in section 6) and the various challenges associated with the management and implementation of interdisciplinary, transdisciplinary, and multisectoral programmes in general, including communication challenges, differences in priorities, and siloed governance and funding schemes.[171,228,229] These barriers inhibit not only the collaborative operations that underpin One Health surveillance, but also the mechanisms and platforms for reporting findings and uptake among decision makers.

Moreover, One Health surveillance is impeded by challenges related to the sharing and integration or triangulation of data that has been collected (although not necessarily synchronously) in different sectors. First, the availability and quality of data can vary greatly across sectors. For example, infectious disease surveillance among humans and livestock is better organised than large-scale surveillance systems for wildlife or companion animals, due in part to the scarcity of species-specific diagnostic tests and to other limitations of wildlife disease surveillance, in which infections are often detected opportunistically and passively (eg, detection due to death).[189] In addition, systematically collected data for important environmental and social drivers of diseases, such as human–wildlife interactions, land use, climate change, food and water, human behaviours, poverty, and social inequality, are often not integrated holistically into health surveillance systems or even linked to other relevant data such as infectious disease surveillance data.[230] Furthermore, even when high-quality data are available within individual sectors, data sharing across sectors and institutions is hindered by an absence of legal, ethical, and operational data sharing frameworks and platforms.[171,189,231] This limited access to data across sectors was reported to be the primary barrier to implementing One Health surveillance in a survey conducted among 185 professionals from 44 countries, 148 of whom perceived One Health surveillance as beneficial, although only 90 applied it in their work.[232] Finally, even if data are shared among institutions, data harmonisation across multiple sources and formats, which is a precondition for data integration, triangulation, analysis, interpretation, and communication to decision makers, can be challenging.[233,234]

Facilitating One Health surveillance presupposes addressing these barriers, including harnessing pre-existing frameworks for governing and funding interdisciplinary, transdisciplinary, and multisectoral collaborations and establishing new ones when necessary; mobilising commitments among stakeholders across public and private sectors and at all levels of government and civil society (including in local communities);[235] advancing the epidemiological evidence base for One Health surveillance and assessing its added value; increasing operational capacity; and addressing challenges related to data collection, sharing, integration, and triangulation, including through structured and sustainable intersectoral mechanisms.[186] To facilitate the implementation of One Health surveillance in Europe, the One Health European Joint Programme developed the One Health Surveillance Codex, through which resources, tools, guidance, and experiences are shared. The Codex is based on the principles of collaboration, knowledge exchange, data interoperability, and dissemination.[236]

In 2019, at a global level and based on a similar ethos, the then-tripartite organisations (FAO, WHO, and WOAH) and more than 100 technical experts developed the Tripartite Zoonoses Guide to inform national zoonotic disease surveillance using a One Health approach. To support operationalisation of the Tripartite Zoonoses Guide, the Multisectoral Coordination Mechanism Operational Tool, the Joint Risk Assessment Operational Tool, and the Surveillance and Information Sharing Operational Tool have been developed and can be applied independently or in tandem to support national capacity for preparedness and response while aligning with existing international policies and frameworks. The Surveillance and Information Sharing Operational Tool was designed specifically to support countries in establishing or strengthening a One Health, multisectorally coordinated surveillance and information sharing system for zoonotic diseases.[237] In addition, the WHO Hub for Pandemic and Epidemic Intelligence, which was launched in 2021 in Berlin, represents a collective and collaborative intelligence endeavour with a focus on reducing inequities and developing evidence-based solutions for better preparedness through open science, partnership, and solidarity, with a strong digital emphasis.[238] Moreover, the One Health Quadripartite has conducted a One Health Intelligence Scoping Study, and a One Health Intelligence System is under development.[239] These initiatives underscore that, despite the barriers that persist, important progress has been made and is underway in the development of One Health surveillance.

2.5 Digital solutions for strengthening One Health surveillance

Digital tools, innovative technologies, and novel data sources have considerable potential to support the widespread implementation of One Health surveillance and to supplement traditional surveillance systems. New portable and low-cost diagnostic technologies, such as those developed during the COVID-19 pandemic,[240] as well as point-of-care imaging, can help address insufficient access to diagnostics in many LMICs.

Non-traditional data sources, including open data, can provide important contextual information to improve understanding of surveillance data. For example, data regarding human and animal travel patterns, weather trends, and consumer behaviour can enhance understanding of public health risks across the One Health spectrum. Social media platforms are also a source of large quantities of complex data and are increasingly engaged in public health surveillance to gain insights into public perceptions of diseases and control measures, including in the context of the COVID-19 pandemic and avian influenza outbreaks.[241,242] The availability of such comprehensive and diverse data sources points to the potential value of big data, which is already frequently used in disease surveillance.[243,244]

Event-based surveillance draws on a wide range of sources to detect any events that have the potential to threaten public, plant, or animal health.[245] As such events ideally need to be reported in real time, digital tools can help to enable rapid, comprehensive surveillance and can bridge the gap between the effort required for active surveillance and the sometimes porous nature of passive surveillance.[246] The organisation Ending Pandemics, for example, is developing digital tools to facilitate community-based surveillance. One example is the AfyaData mobile app, which allows two-way communication between community members and the health system for rapid disease detection in animals and humans in Tanzania and Kenya.[247,248] The Preventing Zoonotic Disease Emergence initiative is similarly conducting workshops with researchers, stakeholders, and community members to develop a global information system that will allow for the real-time detection of emerging zoonoses.[249]

In addition to data collection, digital tools can facilitate the data analysis process in One Health surveillance. For example, data science methods are increasingly used to combine and synthesise data that are both structured (ie, quantitative) and unstructured (ie, text, images, and video). Data science methods can also explore large datasets that cannot be manually interrogated; for example, during the COVID-19 pandemic, several countries used both primary and large secondary datasets to predict trends and the effect of both pharmaceutical and non-pharmaceutical interventions on COVID-19 symptoms.[250] The Norwegian early-warning system Sykdomspulsen (which translates to disease pulse in English) exemplifies the potential for and value of innovation, serving as a real-time One Health surveillance system comprising data from humans, animals, and farms, as well as diagnostic codes from doctor appointments and weather data, with the aim of forecasting outbreaks.[251]

In conclusion, digital tools, innovative technologies, and novel data sources have the potential to facilitate the implementation of One Health surveillance in important ways. Although the persisting barriers to One Health surveillance need addressing, One Health surveillance is evolving and advancing, with future outlooks that include an expanding array of possibilities for supporting healthy and sustainable socioecological systems (panel 4). A synthesis of key messages and gaps related to One Health surveillance is presented in the appendix (p 2).

See Online for appendix

Panel 4: Innovative One Health surveillance in the food system

A One Health approach to surveillance in the food system is essential for targeting the crucial interfaces among humans, animals, plants, and the wider environment where health risks emerge. Given the complexity of food systems, identifying the specific risks that One Health surveillance should address is important.

A One Health approach can help improve existing surveillance practices in food systems by encouraging a wider perspective that encompasses both the natural and social sciences and accounts for issues that sustain or perpetuate inequity, negatively affect livelihoods, and accentuate vulnerability.[252] Such a One Health approach can help produce robust risk assessments to inform actions and regulations, rather than basing these actions and regulations on practices perceived as hazardous.[253] One example of how this can be approached is offered by Béné and colleagues, who propose computing aggregate or composite sustainability scores that encompass environmental, economic, social, and food and nutrition dimensions, which can be tracked over time and used to produce national sustainability maps.[254] However, the proposed 27 indicators do not include animal-related concerns, such as animal welfare, and they have a strong focus on agriculture-related and consumer-related indicators, as opposed to wider food-system metrics.

Innovation and progress in data science and digital methods bring many opportunities for data systems that support health-related surveillance, sustainability monitoring, and interventions in the food system. For example, the potential of blockchain technology in the contexts of traceability, transparency,[255] and the public health field[256] could offer One Health-aligned, innovative, safe, and transparent ways of sharing information across food systems. In addition to tracing relevant production information and enabling consumer choice, blockchain technology could help build trust and ensure authenticity. Advances in machine learning can also be used to predict consumer behaviour for purposes of forecasting demand more accurately,[257] and digital nudges can help personalise food choices,[258] which could promote more sustainable eating. Technologies such as whole-genome sequencing[259] and blockchain[260] are being applied to accelerate the tracing of foodborne pathogen sources for appropriate intervention. Radiofrequency identification technologies for livestock management and meat supply-chain traceability have been applied to improve food safety and security.[261] Although these technologies hold considerable potential, they might only be marginally relevant, if relevant at all, for informal food systems.

Diverse digital tools in the form of apps and platforms have sprung up over a short period of time and have revolutionised activities, some of which might also be useful for surveillance purposes.[262] For example, the One Health AfyaData App uses mobile technology to enable users to engage with infectious disease detection in their communities, thereby keeping their animals safe and reducing the risk of spreading zoonotic pathogens to humans.[247]

In summary, future One Health-oriented food system surveillance is expected to incorporate composite indicators that capture the multiple outcomes that food systems generate, both positive and negative, in line with agreed national, regional, and global targets, and facilitated by new digital technologies and tools that enable easier, more transparent, accessible, and decentralised information exchange.

3. Infectious diseases

Traditionally, infectious diseases have constituted a primary domain of One Health scholarship and

intervention. Although the purview of One Health is expanding, infectious diseases prevail as a central concern, especially in the wake of the COVID-19 pandemic, which has made clear the need to strengthen global health security by improving pandemic prevention and preparedness.[263] Nevertheless, infectious diseases constitute more than pandemics. Engaging the One Health ethos (panel 2) and socioecologically oriented One Health perspective (section 1) advanced by this Commission sheds light on the complexities of infectious diseases, including the drivers of pathogen emergence, spillover, and spread, and the impact of infectious diseases throughout the socioecological system. One Health offers an invaluable, interdisciplinary, transdisciplinary, multisectoral, and socially and ecologically responsible approach to infectious disease prevention, detection, preparedness, and response.

3.1 Diseases shared between animals and humans (zoonoses)

In 2001, 868 (61%) of the 1415 species of infectious organisms known to be pathogenic to humans were zoonotic (ie, transmitted between humans and other animal species).[264] In 2020, more than 70% of more than 400 emerging infectious diseases were of zoonotic origin, according to an IPBES report.[160] A study published in 2021 found food production animals to be primary hosts or amplifiers for 74 (37%) of 202 zoonotic, emerging infectious disease events.[265] Importantly, the transmission of zoonoses often extends far beyond the transmission of a pathogen from a single animal host to a human. Approximately 77% of pathogens that infect livestock and 91% of pathogens that infect domestic carnivores infect more than one other species.[266] Research published in 2021 suggests that pathogen host ranges are poorly understood, and although many of these pathogens show capacity for interspecies transmission, they often become recognised as important only when they threaten privileged human populations.[267] An example is the outbreak of mpox, which was identified in many parts of Africa more than a decade ago, but has only received global attention in the past few years following its emergence in Europe and North America.[268,269]

The insufficient attention and resource allocation for disease prevention and control in under-privileged populations, and the disproportionate focus on biomedical countermeasures and other forms of support as opposed to a One Health approach, are of central concern regarding neglected tropical diseases (NTDs).[270,271] NTDs are a group of preventable diseases that predominantly and persistently affect communities experiencing poverty, with especially pronounced vulnerability among women and children. These diseases are often chronic and result in substantial morbidity and severe social and economic consequences. Although mortality from NTDs is not as high as from diseases that attract more global attention, such as AIDS, tuberculosis, or malaria, the disease burden that they present is just as important. Most NTDs are zoonotic and parasitic or bacterial, including many that are vector-borne.[175] Due to the complex interactions between humans, other animals (including insects), and the environment that characterise most NTDs, successfully meeting the targets of the NTD Road Map 2021–30 will not be possible without a One Health approach, as recognised in the WHO One Health companion to the NTD Road Map.[272]

Several anthropogenic drivers of pathogen emergence, spillover, and spread are recognised, including climate change, biodiversity loss, increased contact between humans and other animals due to habitat encroachment (due to agriculture, deforestation, and other land use change), and global trade.[273–275] Some infectious agents that were believed to be primarily transmitted among humans, with or without vector involvement, are now being shown to have a zoonotic component. For example, evidence increasingly suggests that cattle might be playing a role in the epidemiology of *Schistosoma haematobium*, a schistosome believed to infect only humans, through hybridisation between *Schistosoma bovis*, a schistosome known to infect cattle, and *S haematobium*.[276,277] Likewise, *Ascaris suum* in pigs and *Ascaris lumbricoides* in humans have also been shown to cross-transmit and hybridise.[278] A One Health approach to Guinea worm eradication at an earlier point could have prevented domestic dogs from emerging as a reservoir of Guinea worm infection, even though the disease has been nearly eradicated from human populations.[279]

Concerns about cross-species pathogen transmission are compounded by the fact that infectious agents evolve, which could enable them to spread more efficiently between hosts. For example, SARS-CoV-2 is largely thought to be of bat origin,[280,281] having spilled over into human and other animal populations due to anthropogenic practices, including wildlife trade and markets.[181,282] Several new variants have evolved in the human population, but the virus has also been transmitted to a wide variety of animals, including cats, non-human primates, hamsters, ferrets, and mink.[283] Infected mink have been shown to transmit SARS-CoV-2 back to humans, causing concern that potential mutations in infected animals could reach the human population.[284] However, beyond interspecies transmission, pathogens also evolve through codivergent events. Molecular studies have shown that divergence between herpes simplex viruses in great apes and herpes simplex virus 1 in humans is probably representative of a codivergence event between gorillas and humans (meaning that the virus mutated as its original host evolved into new species). Other findings are suggestive of more cross-species transmission events in the past 3 million years.[285] Research also shows that the measles virus diverged from the rinderpest virus, a cattle pathogen, and potentially emerged following spillovers from cattle to humans during the domestication process as early as the 6th century BCE.[286]

3.2 Non-zoonotic infectious animal diseases

With the world now highly sensitised to epidemics and pandemics brought about by spillover of animal pathogens to humans, the scope of One Health should not be limited to zoonoses. Several non-zoonotic infectious animal diseases are of substantial concern because of their effect on the health of livestock, wildlife, aquatic species, companion animals, and insects, in addition to their effect on biodiversity and plant health, international food systems and trade, access to high-quality nutrition, antimicrobial use, livelihoods, and economic development.[287]

The conceptualisation of emerging infectious diseases (ie, infectious diseases that have newly appeared in a population or that have existed but are rapidly increasing in incidence or geographical range[288]) common in the medical and veterinary fields could be extended to plants, allowing for the analysis of factors involved in emergence, as well as of the overall effect on biodiversity and the wellbeing of humans and other animals.[289] Findings from a 2004 study[289] showed the differences and similarities between the groups of pathogens causing emerging infectious diseases and between the drivers of disease emergence among plants, humans, and wildlife. Viruses were found to be the most common agent and to cause a similar proportion of disease across all species. Bacteria caused a much lower proportion of emerging infectious diseases in plants than fungi caused, with the trend reversed for emerging infectious diseases in humans, in whom fungi caused a slightly lower proportion of emerging infectious diseases compared with wildlife. In terms of the drivers of disease emergence, pathogen introduction is the most important driver of emerging infectious diseases in plants and wildlife, which prompts consideration of the effect of globalised trade on the frequency of disease events in these populations.[289]

Non-zoonotic infections among plants and animals (including insects) directly affect production metrics, human livelihoods, and health. Examples of potential

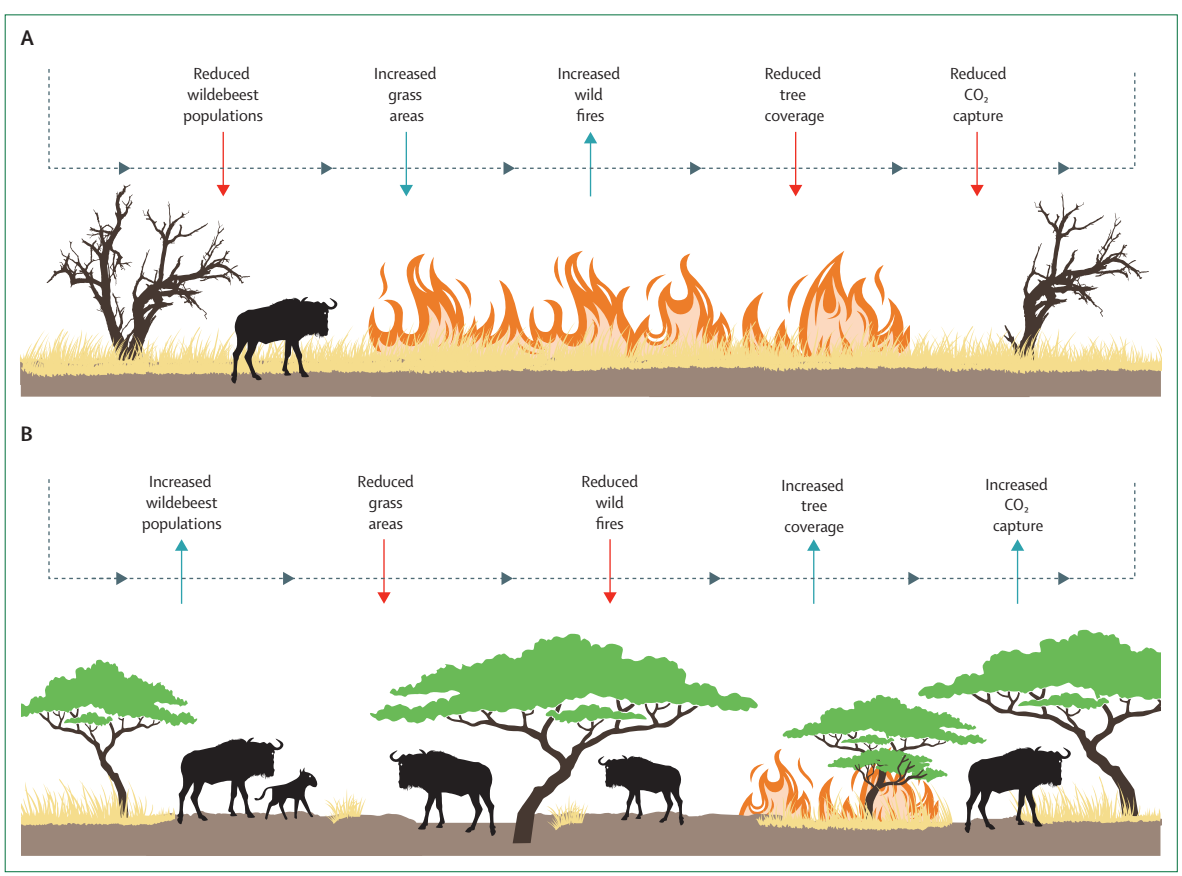

Figure 5: **A disease-mediated trophic cascade in the Serengeti National Park in Tanzania**
In an ecosystem in which humans, other animals (including insects), plants, and pathogens continuously interface, changes have the potential to trigger powerful systemic disturbances, which are often called trophic cascades. Although most trophic cascades originate with predators (ie, top-down cascades), plants, phytoplankton, zooplankton, and even pathogens can also be triggers (ie, bottom-up cascades). A well known example of an infection-mediated trophic cascade with strong links to the health of animals and the environment has been described in the Serengeti National Park in Tanzania.[310] The two images depict (A) the scenario observed while rinderpest (caused by the morbillivirus) was present among wildebeest in the Serengeti National Park in Tanzania, and (B) the situation after rinderpest vaccination and eradication campaigns among cattle. Ultimately, by altering the carbon dioxide concentrations in the soil and biomass, this cascade was of importance for climate change as well. This figure was produced using data from works by Dobson and by Holdo and colleagues.[310,311]

areas of impact include the yield, quality, and safety of saleable meat, fish, milk, vegetables, fruits, crops, and eggs; feed conversion and growth; honey and wax production in food, cosmetic, and other industries; clothing production based on insects and animals, such as silkworms, sheep, and South American camelids; and animal-supported work, such as the use of donkeys, horses, cattle, llamas, camels, and dogs in agriculture, transportation, security, and diagnostics.[290–294] The costs associated with animal and plant diseases and their effect on human wellbeing, livelihoods, and national economies have not been adequately explored and require more investigation.[295–299]

Foot-and-mouth disease (FMD), which is widespread globally and endemic in several parts of Asia and in most of Africa and the Middle East, is a serious viral disease that predominantly affects cloven-hoofed animals and provides an example of the important human health and economic ramifications of animal disease. Although FMD has been documented as transmissible to humans and hence could be classified as a zoonotic disease, it infects humans with great difficulty and with little clinical effect.[300] Although the disease does not cause high mortality rates in adult animals, FMD has the potential to rapidly infect numerous livestock and wildlife species, and morbidity can approach 100% in susceptible animal populations.[301,302] Thus, severe economic losses due to FMD outbreaks can quickly affect families with subsistence farms and animals.[303] Both the diagnostics and mitigation measures involved in containing FMD outbreaks, including culling, quarantine, and mass vaccination, demand considerable resources and have substantial national and international economic implications.[304] Factors that inform decisions on mass culling differ from country to country. For example, nations with large export markets might, in response to outbreaks, conduct mass culling (ie, stamping out), as the associated costs (including compensation) are likely to be dwarfed by trade impacts.[305] However, resistance to mass culling on sociocultural grounds (ie, implications for farmer livelihoods, wastage, environmental concerns about carcass disposal, and ethical considerations, including for animal welfare) is driving the evaluation of alternative approaches.[306,307]

3.3 Pandemics and panzootics

Epizootics and panzootics are the animal equivalent to epidemics and pandemics in humans, with panzootics defined as infectious disease outbreaks in animals that spread across large regions, as occurred with rinderpest in the 18th century.[308] Rinderpest provides a powerful example of the health and economic impacts of panzootics. When the Italian colonisers brought Zebu cattle from India to Ethiopia, they introduced rinderpest to Africa, leading to the decimation of cattle populations along the east coast towards South Africa. More than 90% of African cattle and innumerable wildlife perished.[309] The consequence was massive famine and death among large human populations when the draught animals needed for ploughing were no longer available and cereal production collapsed.[309]

The eradication of rinderpest benefitted not only human economies, but also the ecosystem at large, via the well known trophic cascade in the Serengeti National Park in Tanzania (figure 5).[310] Specifically, the eradication of rinderpest from the cattle population permitted the wildebeest population to substantially increase, which led to a decline in the frequency of fires, due to increased grazing, a resulting overall reduction in grassy terrain, and a marked increase in tree density. Together with the increased grazing intensity of the wildebeest and reduced fires, this increase in tree density might have shifted the Serengeti from being a net source of carbon to being a net sink for carbon (ie, absorbing more carbon dioxide than releasing), with clear benefits for the local ecosystem.[311] This example illustrates the multiple and complex biotic and abiotic links within an ecosystem and how important a holistic One Health perspective and systems-oriented approach can be for understanding these feedback loops.[312]

Other examples of panzootics include an amphibian fungal disease caused by the chytrid pathogen *Batrachochytrium dendrobatidis*, which has decimated global amphibian populations at an alarming rate. More than 500 amphibian species have declined in number, and as many as 90 species have been rendered extinct due to this chytrid fungal pathogen, thus constituting a severe biodiversity crisis.[313] Many amphibian populations around the world were completely lost before the problem was even identified.[314] Studies have highlighted how this disease is interlinked with climate changes that are favourable for pathogen proliferation and how the disease affects microbiome–pathogen interactions, particularly in the skin microbiome of frogs, acting as a driver of bacterial community change during natural disease dynamics.[315,316]

The prevention and management of epizootics and panzootics require far greater attention than has been granted thus far, given how closely these outbreaks are linked to global health and economic wellbeing,[317] and given the impact on the socioecological system at large. For example, although African swine fever cannot infect humans, anthropogenic forces (predominantly transportation) are perhaps one of the most notable risk factors for the spread of the disease.[318] Due to its ability to kill up to 100% of the pigs on a farm,[319,320] African swine fever seriously threatens the global pork industry, which was estimated to be valued at US$434·35 billion in 2025.[321] China was home to half of the world's domestic pig population in 2018,[322] but the onset of the African swine fever panzootic in 2018 resulted in the demise of more than 40% of their national pig population and more than $140 billion in losses at the beginning of 2020.[323,324] A synthesis of key messages and gaps related to infectious diseases and One Health is presented in the appendix (p 3).

4. AMR

4.1 Introduction to One Health and AMR

AMR is recognised by WHO as a global health threat,[325] meaning that WHO calls for urgent and prioritised actions on multiple fronts by governments, industry, research funders, and other relevant actors, as summarised in the report from the UK Government-commissioned independent review on AMR in collaboration with the Wellcome Trust.[326] AMR has been explored in detail by the *Lancet Infectious Diseases* Commission on AMR, and the updated report published in 2020 provided valuable data synthesis, summarised national and international actions, identified AMR trends in human and veterinary settings, and flagged important knowledge gaps.[327] In addition, a systematic analysis conducted in 2019 estimated that AMR was associated with nearly 5 million deaths that year, of which 1·27 million (25·4%) were directly attributable to bacterial AMR.[328] Thus, our focus in this Commission lies specifically on the One Health aspects of AMR not fully covered in previous scholarship and on synthesising the evidence from the most recent genomics studies.

Possibilities to study rates and routes of transmission of bacterial pathogens and AMR across different hosts were substantially improved after the introduction of bacterial population genomics, as shown in 2010 in one of the earliest studies illustrating intercontinental and hospital transmission of methicillin-resistant *Staphylococcus aureus* (MRSA).[329] Genome-scale information is typically a necessity for any robust investigation of the timeline and routes of transmission of bacteria, due to slowly accumulating mutations that make it difficult to draw reliable conclusions from studies using marker gene-based approaches. In addition, phylodynamic analysis based on genome-scale information can reveal the origin of particular AMR clones and inform investigators about which ecological conditions facilitated their emergence and spread.[330] In a short time period, bacterial population genomics has already challenged many established ideas concerning both routes of pathogen transmission (such as the discovery of human movement-mediated cholera epidemics[331]) and the emergence of methicillin resistance in *S aureus,* before the clinical use of methicillin as a byproduct of much earlier emerged penicillin resistance.[332] Specifically, emergence of methicillin resistance in *S aureus* has been shown to have come about as a co-adaptation to dermatophyte-infected hedgehogs, which, in turn, became a vector host for zoonotic introductions, including transmission to livestock and humans.[333] This scenario reflects why the One Health approach to understanding AMR beyond antibiotic use is crucial.

4.2 Bacterial pathogens within the contexts of One Health and AMR

To enable a synthesis of acquired knowledge about the transmission rates of bacteria across different host types within the contexts of One Health and AMR, we searched PubMed for original population genomic studies published between Jan 1, 2015, and June 5, 2020. We focused on the critical-priority and high-priority bacterial pathogens, as classified by WHO in 2017.[325] In addition, in a separate survey, articles of relevance for One Health and AMR were identified,[334–336] and important population genomic studies that were potentially missing from the original survey output were sourced by final expert screening. The review was subsequently extended with relevant studies selectively added up to Jan 31, 2024, to capture any advancements made in population genomic studies in LMICs. The PubMed search criteria are listed in the appendix (pp 8–15).

To summarise the pathogen inclusion and exclusion criteria, *Helicobacter pylori* and *Neisseria gonorrhoeae* were excluded as strictly human pathogens. In the interest of scrutinising the highest-priority pathogens only, *Streptococcus pneumoniae, Haemophilus influenzae,* and *Shigella* spp were excluded as both medium priority and mainly human pathogens. The included bacteria are therefore *Enterococcus faecium*, *S aureus*, *Campylobacter* spp, *Salmonella* spp, *Acinetobacter baumannii*, *Pseudomonas aeruginosa*, and Enterobacteriaceae (ie, extended-spectrum β-lactamase-producing, carbapenem-resistant, and third generation cephalosporin-resistant organisms within *Klebsiella pneumonia* and *Escherichia coli*). The included high-priority pathogens have shown pathogenic potential across a wide range of hosts, including not only humans, but also both wild and domesticated animals, in addition to having environmental reservoirs. The emergence of extensively high-throughput whole-genome sequencing-based methods has greatly facilitated the investigation of bacterial pathogen transmissions between different hosts and distant geographical locations, even up to a global scale.[334]

4.3 A One Health approach to combating AMR: one size does not fit all

The evidence synthesis from our review (appendix pp 8–15) strongly points to the generic conclusion that dissemination of pathogenic antimicrobial-resistant bacteria from the environment and food production chains into the human population is controlled by both ecological opportunity and sustained transmission pressure. In the highly regulated and controlled food production and water systems typical in HICs, an increasing body of evidence suggests that such dissemination tends to be rare. Hence, the main drivers of resistance in the human and animal populations in HICs are the human and veterinary use of antibiotics, which act in parallel in their target populations. For some multidrug-resistant pathogen species, successful transmission and subsequent host adaptation to humans has happened slowly. Such events, even when rare, could have considerable long-term consequences in terms of infection and AMR burden. Evidence overwhelmingly supports the conclusion that hospital-adapted clones circulating among patients are the primary drivers of the

Panel 5: **Case study on the success of One Health surveillance systems for eradicating livestock-associated methicillin-resistant *Staphylococcus aureus***

Methicillin-resistant *Staphylococcus aureus* (MRSA) has become increasingly linked to morbidity, mortality, and health-care costs in the past few decades.[337] The main route of MRSA transmission is between humans, but extensive evidence shows occasional transmission between humans and other animals, followed by onward spread in either population—which therefore has implications for both human and animal health.[338–341] Norway, Denmark, and the Netherlands share similar MRSA mitigation policies and a corresponding low burden of MRSA in their human populations. Individuals with suspected bacterial colonisation are screened upon admission to health-care facilities and kept in isolation until the test results become available.[342–344]

However, the same countries differ substantially in their strategies for mitigating livestock-associated MRSA, which results in different colonisation and disease incidence rates and has implications for potential spillover to the human population. Since 2014, Norway has conducted yearly active surveillance of MRSA in pig populations with the objective of contact tracing and eradication.[345] This surveillance, combined with the negligible import of live pigs, has resulted in a livestock-associated MRSA-free pig population in Norway. The Danish strategy to reduce the burden of livestock-associated MRSA was launched in 2010 and has targeted the reduction of antibiotic use on farms.[346] This strategy does not involve eradication of livestock-associated MRSA-positive herds and, despite a substantial reduction in antibiotic use, a survey from 2016 found a livestock-associated MRSA prevalence of 88% in finisher herds.[347,348] In 2010, the Dutch government launched a plan to reduce antibiotic use in industrial farming but, in 2016, up to 99% of pigs in the Netherlands carried livestock-associated MRSA in their nares.[349] Livestock-associated MRSA is now more prevalent than non- livestock-associated MRSA in Dutch hospitals in the southern Netherlands, where high-density industrial pig farming is common.[350]

The countries' different strategies are examples of the importance of a One Health approach to addressing antimicrobial resistance. The yearly surveillance of MRSA in food-producing animals clearly accounts for Norway's success in its efforts to keep livestock-associated MRSA out of its human population. The strategy is an excellent example of how continuous surveillance of targeted pathogens in both human and animal populations can lead to positive outcomes for animal and human health, lower the burden on health-care systems, and reduce economic losses.

AMR burden faced by health-care systems in HICs. Nevertheless, evidence also suggests that the One Health approach can be paramount for the eradication of zoonotic and anthropogenic dissemination of specific pathogens, as illustrated by the case study on the livestock-associated MRSA in Norway and the Netherlands (panel 5). In settings with ample ecological opportunities and sustained transmission pressure, dissemination of AMR clones to the human population from the environment and food production systems can be rapid, and their circulation can become widespread, as shown by several studies (eg, the case of colistin resistance in China).[351] A wider body of evidence is now emerging from LMICs regarding the linked roles of antibiotic use in animal husbandry and human populations as drivers of frequently shared resistant bacteria between these two settings (figure 6).[352–355] AMR evidence from LMICs points to the strong value of a One Health approach to surveillance and control systems, legal regulation, and interaction with policy makers in LMICs. Our review highlights remaining knowledge gaps regarding the detailed dynamics and interplay of different factors that contribute to successful AMR pathogen transmission between humans and other hosts in LMICs. The knowledge gaps we identified suggest that both governmental and intergovernmental agencies should take an active role in engaging the One Health approach in the battle against the AMR crisis in LMICs.

Although the main driver of AMR is the overuse and misuse of antimicrobials among humans and other animals,[356] antimicrobials also accumulate in the environment. However, the environment's role in the development of AMR has received little attention despite it being of crucial importance for not only the transmission of resistant strains, but also the development of new resistance factors in pathogens, albeit rare.[357] AMR drivers mainly found in soil and water, such as heavy metals (mainly from manufacturing and industrial practices), biocides (including formaldehyde and chlorhexidine, which are mainly used as disinfectants), nitrogen fertiliser, and microplastics, can contribute to the development of AMR via different mechanisms.[357,358] In addition to molecular AMR processes, socioeconomic factors (including social development, poverty, and governance) seem to play an important role.[356] The climate change crisis has also been shown to contribute to AMR.[146] Although drivers of AMR vary greatly between countries and regions,[359] the potential risks remain increasingly global due to unprecedented mobility, which facilitates rapid, transnational transmission of resistant pathogens and vectors.

4.4 Adapting global efforts to address AMR using a One Health approach

The One Health approach to AMR requires a community-driven process of identifying national priorities, and these priorities then need to inform governance and interventions. In January, 2021, following recommendations made by the UN Interagency Coordination Group on AMR, prominent global leaders in science, industry, and government

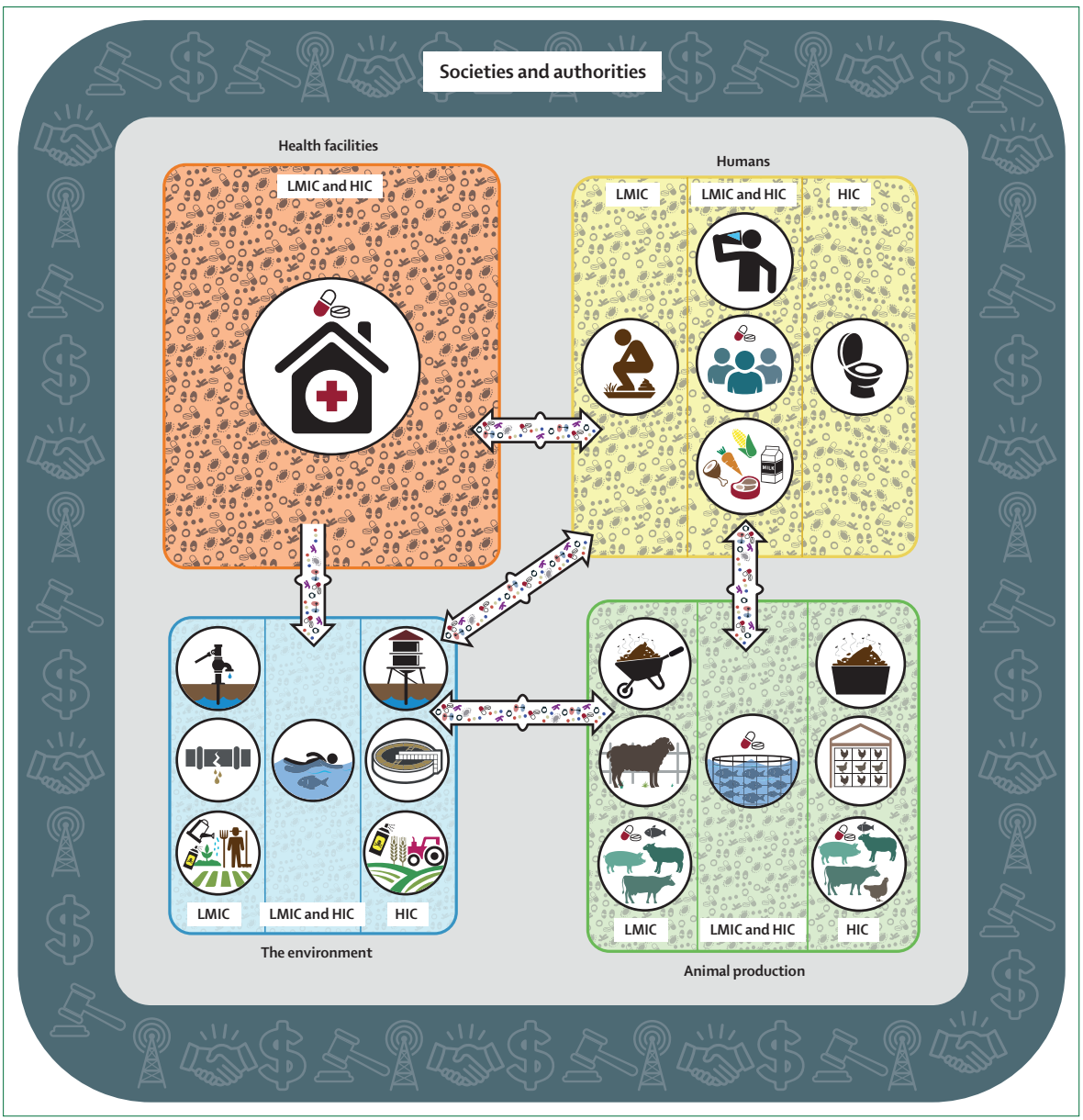

Figure 6: **Antimicrobial resistance transmission in LMICs and HICs**
Variations in the colour and microbial backgrounds in each domain represent the varying degrees of AMR transmission, showcasing the highest levels in health facilities, the second-highest among humans, the second-lowest in the animal production industry, and the lowest in the environment. The flow of AMR transmission between these domains is conveyed by multidirectional arrows, although the modalities and rates of transmission require more investigation. The roles of legislation, civil society, the media, and economic forces are represented by the icons in the background pattern. Agroecological practices vary across countries and regions with regard to the intensity and extent of farming, land use, pest management, animal species, water sources, and available technologies. Consequently, the commonly practised yet problematic use of wastewater irrigation in LMICs, depicted by the watering can, is another potential driver of AMR in LMICs. In aquaculture practices, antibiotic use is widespread in both LMICs and HICs. However, ecological differences between the two generally imply a higher risk for AMR dissemination in LMICs. AMR=antimicrobial resistance. LMIC=low-income and middle-income country. HIC=high-income country.

were convened by the One Health Quadripartite to form the One Health Global Leaders Group on Antimicrobial Resistance.[360,361] This collaboration aims for the creation of common goals and visions through innovative partnerships, political and multisectoral engagement, and synergy across the One Health spectrum of humans, animals, plants, food, feed, and the environment. This initiative also aims to help strike a better balance between the security-driven agendas of HICs and the development needs across the human, animal, and environmental sectors of LMICs. In addition, the One Health Joint Plan of Action, supported in an advisory capacity by the OHHLEP, has an action track dedicated to AMR.[53,174] The Antimicrobial

Resistance Multi-Partner Trust Fund also focuses on addressing AMR through strategic collaboration, sustainable streams of capital, and Sustainable Development Goals-focused responses that support national governments in implementing and maintaining the One Health approach.[362]

Both existing and new initiatives to combat AMR should emphasise comprehensive access to effective antimicrobials globally, with appropriate stewardship, community-centred approaches to national priority setting, and upscaling of investment in the most effective preventive interventions. These preventive interventions include improved infection prevention and control; water, sanitation, and hygiene; and vaccination programmes across both human and animal health systems. A synthesis of key messages and gaps related to One Health and AMR is presented in the appendix (p 4).

5. Non-communicable diseases

5.1 The One Health connection between communicable diseases and NCDs

NCDs cause more than 70% of human deaths worldwide and 80% of years lived with disability.[363] Consequently, the economic implications of NCDs are considerable, with projections indicating a global cumulative cost of US$47 trillion by 2030 for cardiovascular diseases, diabetes, mental illness, and chronic respiratory diseases.[364]

Although communicable diseases and NCDs are most commonly treated as distinct entities, the two disease types have interconnections. For example, the gut microbiota has been implicated in NCD aetiology and is often similar in people living in close proximity to one another, such as in familial and social networks,[365] as well as among humans and pets living in the same household.[366] NCDs might be communicable to some extent via the microbiota.[367] Furthermore, chronic diseases can occur as a result of infectious agents. For example, in 2018, 2·2 million new cancer cases (13% of all cancer cases) were attributable to infections.[368] By 2050, some experts have predicted that infectious agents will be a major causal factor for the majority of human cancers.[369]

Communicable diseases and NCDs share many environmental drivers, such as air pollution (as discussed in section 1.4). The social determinants of health, such as gender, education, employment status, and race, are also important drivers. Unequal and insufficient economic, social, political, and health resources have long been established as risk factors for the occurrence and negative outcomes of both communicable diseases and NCDs.[370,371] Similarly, anthropogenic changes to the environment (as discussed in section 1) affect the prevalence and distribution of both communicable diseases and NCDs. Many of the diseases that were previously assumed to be exclusive to humans, such as stress or eating disorders, are now understood to also occur in animals.[372] The environmental changes that affect human NCD risk are therefore also likely to affect the NCD risk of other animals living within the same environment. All of these interconnections underscore the complex health interdependencies between humans, other animals, plants, and the wider environment, as well as the policy implications across all sectors that are important for health outcomes. Also notable is the overall need for better understanding and cooperation to help tackle the complex and growing burden of NCDs.[373] Although One Health has yet to be engaged in efforts to address NCDs, the One Health approach advanced by this Commission is highly relevant.

5.2. A One Health approach to NCDs in humans, other animals, and the shared environment

One Health has historically evolved from One Medicine and comparative medicine, which focus primarily on the biological aspects of disease that are shared between humans and other animals (ie, diagnosis, treatment, and prevention). NCDs have been a focus within One Medicine and comparative medicine,[374] but with insufficient appreciation of the interdependent relationship between the health of humans and other animals on the one hand, and that of the wider ecosystem on the other. Although NCDs have traditionally received little attention within One Health research, a socioecologically oriented One Health approach to NCDs can facilitate understanding of the complex interactions between humans, other animals, and their shared environment, including a comprehensive framework of shared risk factors and a systemic approach to health and sustainability that goes beyond biomedicine and considers the social and environmental determinants of health.[76]

Humans and animals, particularly companion animals, often share a social environment, which can affect health and wellbeing. For example, a person's social network can be a risk factor for obesity, with an increased risk of obesity occurring when a close social contact becomes obese.[375] Such influence of social ties on obesity incidence might even extend to companion animals, with recent research showcasing a close link between obesity risk for dogs and the weight status of their owners.[376] Alternatively, dogs can act as a positive source of social support and motivation for physical activity, with research suggesting that dog owners are statistically significantly more likely to meet physical activity guidelines in comparison with people without a dog, with the benefits of increased physical activity extending to improved mental wellbeing and joint health.[377,378]

A multitude of factors related to a person's socioeconomic environment substantially affect their risk for mental illness,[379] and these factors are thought to have a similar effect on animal health.[380,381] For example, areas with higher rates of violence between humans also have higher rates of animal abuse and dog fighting.[382]

Moreover, just as adverse childhood experiences are increasingly linked to pathology in later life, a parallel phenomenon has been found in dogs, with respect to the association between major stressors experienced as a puppy and behavioural problems, such as increased aggression and fear, later in life.[383] In these ways, a One Health perspective on mental health can help us to understand the essential mechanisms underlying mental illness and the environmental factors that contribute to its occurrence in both humans and other animals.

High and extreme temperatures have been linked to acute ischaemic events.[384] Heat stress and hyperthermia affect the nervous system in complex ways that can result in seizures, strokes, and cognitive deficits.[385] Similarly, heat directly affects animal health and can lead to an increased incidence of metabolic disorders, oxidative stress, and immune suppression in livestock.[386] Laboratory studies have even suggested that some animal species might have impaired cognition at high temperatures, including impaired learning, memory, and decision-making abilities.[387] Interestingly, intense heat also affects the productive performance of dairy and beef cattle, leading to a reduction of quality in the corresponding food products. The economic loss incurred by the livestock industries due to heat stress was estimated to be US$1·7 billion in 2003, which equated to approximately $2·5 billion in 2021.[388,389] Increased temperatures and unpredictable weather conditions also disrupt food production and water availability, which can lead to food insecurity, increased malnutrition, and chronic disease among humans and animals.

Humans and animals living in the same environment are often exposed to similar types and concentrations of pollution. In 2015, 21% of all human deaths resulting from cardiovascular disease, 26% of all ischaemic heart disease deaths, and 23% of all stroke deaths were directly attributable to pollution, including air pollution, water pollution, and exposure to toxic chemicals.[390] Air pollution (primarily pollution with fine particulate matter [$PM_{2·5}$]) has been consistently linked to cardiovascular disease,[390,391] chronic obstructive pulmonary disease, lung cancer,[373,392,393] dementia, and Alzheimer's disease.[394–396] In a 2016 report, WHO estimated that 92% of the global human population was living in areas where the ambient (ie, outdoor) $PM_{2·5}$ concentrations exceed the recommended limit of an annual mean of 10 μg/m³.[397] A large proportion of the non-human animal population is therefore probably living in areas of excessive exposure as well. Although the research is scarce, evidence suggests that animals are similarly affected by air pollution exposure as humans.[398]

Pollution from microplastics is another environmental challenge of great importance, with microplastics being ubiquitously present in the atmosphere; soil; food; and marine, fresh, and drinking water.[399] Microplastics have also been implicated as environmental drivers of AMR (as discussed in section 4). Humans and other animals can ingest microplastics through contaminated food or water.[399,400] Extremely small particles have even been able to cause negative effects in plants and microbiota.[400] Especially harmful are the chemicals that are intentionally added during plastics production, including, for example, bisphenol A and phthalates, both of which are known endocrine disruptors.[399] Chemicals that interfere with hormone regulation are associated with an increased risk of obesity, diabetes, reproductive disorders, and some cancers. Marine mammals, for example, are now well known to be vulnerable to mammary cancers in response to the same endocrine disruptors that increase risk among female humans.[401,402]

Another group of pollutants of great concern are PFAS (as discussed in section 1). These chemicals contain carbon–fluorine bonds, which are one of the strongest chemical bonds in organic chemistry, making them non-biodegradable.[403] PFAS permanently pollute water and soil, and accumulate in humans and other animals via food, water, and consumer goods, but are widely used in industry and consumer products for reasons including their grease-repellent, dirt-repellent, and water-repellent effects.[403–405] PFAS cause pathophysiological changes and diseases in various systems throughout life, including the immune, metabolic, circulatory, respiratory, endocrine, and reproductive systems in humans and other animals. These chemicals have been shown to cause cancer and have a pronounced effect on the nervous system in humans and other animals,[404,405] but have been found in wildlife around the world, with uncertain health effects and consequences, including low immunity and infertility, which might also affect biodiversity.[406] Measures to reduce or ban PFAS could benefit from an integrated One Health approach across systems and sectors (eg, health, environment, water, food, politics, industry, and trade). The global regulations around PFAS that are in place, mainly through the UN's Stockholm Convention and US-based provisions,[407,408] have been criticised for lacking ambition, in part because of uneven implementation, with LMICs lagging behind.[409] Global, regional, and national One Health governance (as discussed in section 8.1) is required to hold industry accountable and address the global and intergenerational inequities that are at stake in the continued production of PFAS.

5.3 Opportunities for shared solutions

The deeper understanding of the complex interconnections between humans, other animals, plants, and the wider ecosystem that One Health advances facilitates the development of interventions that improve NCD outcomes across multiple domains. For example, the One Health approach promotes environmental conservation and animal welfare and wellbeing, and advocates for agricultural practices that prioritise equity, sustainability, and health (as discussed in section 7). Healthy and sustainable ecosystems, as well

as access to safe and nutritious food, are essential for all humans and other animals and play an important role in the prevention and management of NCDs. The bonds between humans and other animals can also be a source of mutual support in the management of NCDs, such as obesity and mental disorders.[410] However, companion animals also contribute to biodiversity loss by preying on mammals, birds, reptiles, amphibians, and insects; transmitting diseases;[411,412] and contributing to greenhouse gas (GHG) emissions due to their meat-based diets (as discussed in section 7.2).[413] Solutions could include avoidance of overfeeding, a transition to sustainable diets,[414] and population control, including through restrictions on numbers of companion animals and the possible introduction or revision of companion animal taxes.[415]

One Heath strategies also promote sustainable urban planning and aim to mitigate climate change, improve access to clean water, and decrease air pollution by banning the burning of fossil fuels, improving public transport systems, expanding bike paths, incentivising the number of zero-emissions vehicles, and handling air travel more restrictively, among other measures. In addition to reducing GHG emissions, such strategies would automatically decrease diseases associated with air pollution and heat waves among humans and other

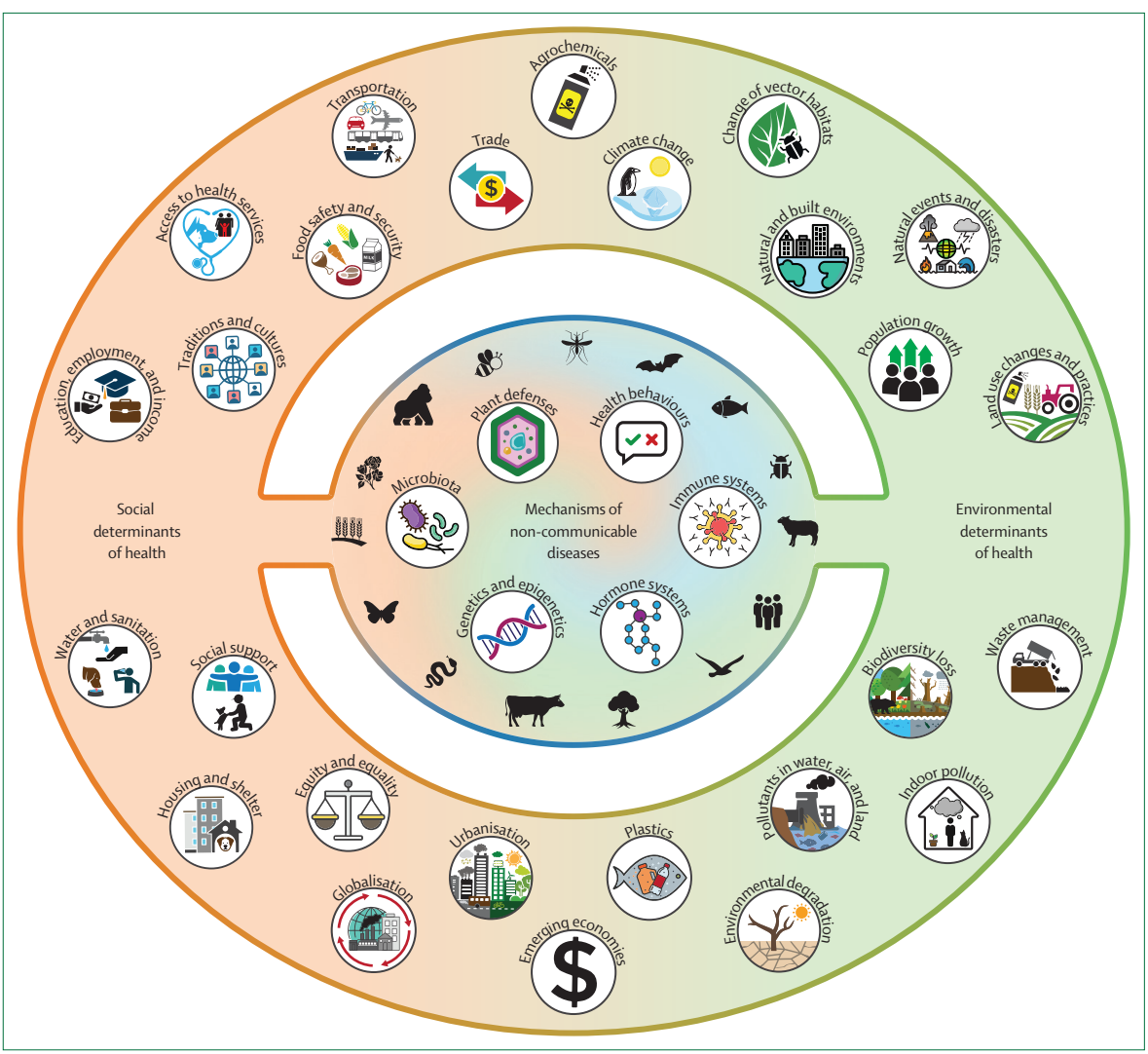

Figure 7: **The One Health non-communicable disease wheel**
Shared determinants affect health through particular mechanisms of health and disease. For example, exposure to air pollution is associated with increased inflammation in both animals and humans.[398,416,422–424] Plants also have an immune system with striking similarities to that of animal species, and plants produce hormones in response to pathogens and for disease resistance.[425–429] The social and environmental determinants of health are not separate entities, but together could be qualified as determinants of One Health.[430,431] For example, the demands of the growing human population have led to more intensive food production systems, including the increased use of agrochemicals such as pesticides. These pesticides in turn affect the health of pollinators, biodiversity, pollination services, and crop yield.[432]

animals, promote health by incentivising physical activity, and contribute to social equity by improving mobility and access to economic and social opportunities.[373,416,417] Reducing air pollution will contribute to maintaining plant diversity and improving ecosystem services, such as forest growth.[418,419] Although such changes can be partly influenced by personal choice, policy measures, such as fuel taxation, are likely to be more effective.[373]

Multisectoral collaboration is also required when it comes to NCD surveillance. Global data-sharing platforms that track environmental, animal, and human health trends help to identify risks for both communicable diseases and NCDs. Integrating data from diverse sources, supported by cutting-edge technology, such as pollution monitoring, animal health surveillance, and public health records, can inform more targeted One Health interventions (as discussed in sections 2, 6.3, and 6.4). The WHO STEPwise approach to NCD risk factor surveillance provides valuable data on NCD risk factors, disease incidence, and mortality, but so far is rather anthropocentric, as animal and environmental data have not been included.[420]

International organisations such as WHO, FAO, and UNEP are increasingly collaborating to promote One Health solutions to NCDs, such as through the Global Action Plan for the Prevention and Control of NCDs (2013–30) and its Global Compact (2020–30).[421] However, policies that address AMR, environmental conservation, animal health and welfare, food safety and security, and trade regulations (as discussed in section 6.3 and 7.2) are also crucial for reducing NCDs in humans and other animals, and need to be integrated nationally, regionally, and globally (figure 7). A synthesis of key messages and gaps related to NCDs and One Health is presented in the appendix (p 5).

6. Health-promoting synergies

Many of the most pressing global health and sustainability challenges of our times, including emerging and endemic infectious diseases, AMR, NCDs, food insecurity, climate change, biodiversity loss, and pollution, demand integrated, systems-wide solutions, cooperation between multiple sectors and disciplines, and structural adjustments and shifts in global governance, economics, and ways of knowing and operating.[69] A One Health approach to interventions advances equitable, sustainable, and healthy socioecological systems through collaboration (including joint investment and resource mobilisation, programme design and evaluation, and mutual benefits) across two or more sectors and disciplines,[433] resulting in added value (panel 1). A One Health approach to interventions encompasses diagnostics, vaccines, medicines, and other forms of health promotion and disease prevention and management throughout the socioecological system (as discussed in section 1).

6.1 A One Health approach to diagnostics

Screening for biological risks in humans, other animals, and the environment increasingly uses next generation sequencing (NGS), through which entire genomes of organisms or targeted regions of DNA or RNA can be sequenced.[434] With metagenomic NGS, any genetic material present in a sample obtained from humans, other animals, or the environment can be quickly identified, which allows for a rapid determination of the sample origins and any genetic changes that might have taken place over time. The connection between biological risks to the health of humans, animals, plants, and the wider environment can thus be identified at the molecular level. Superimposing epidemiological methods in a transmission network analysis can also aid in disease surveillance, such as within the food system.[435,436] Additionally, using findings from metagenomic NGS, identifying changes in AMR and in transmissibility, virulence, and other important properties of a pathogen as part of outbreak control and prevention becomes possible.[436]

Rapid, easy-to-use, point-of-care diagnostics used outside of laboratories (eg, using the lateral flow technique at bedside or pen-side, often on the basis of antibody or antigen detection) are in increasing demand.[435,437,438] A growing body of research indicates the potential value of point-of-care diagnostics in multiple species and using different formats.[437,439–443] However, multispecies and context-specific test validation and global alignment of test protocols across species and the environment are needed, with appreciation of the differing diagnostic capacities that tests can have. These capacities can be based on, for example, the parasite stage in humans and animals, as well as on the epidemiological setting, as pointed out by a review of diagnostic tools available to detect the parasite *Echinococcus multilocularis*.[444] Point-of-care formats also exist for nucleic acid-based technology, such as loop-mediated isothermal assays and recombinase polymerase assays, and use of this technology is on the rise.[437]

Innovative approaches with a One Health potential include the CRISPR-Cas technology that first gained popularity because of its genome editing capacity and that has now been applied to diagnostics for infectious diseases and NCDs, such as cancer.[445,446] In the case of SARS-CoV-2, CRISPR-Cas technology was used to develop an assay implemented on a lateral flow strip with single-base specificity for detection of emerging variants, and simultaneously multiplex, to differentiate between different viruses. Under optimal conditions, results can at times be produced within 1 h of sample input.[447] Most recently, a CRISPR-Cas-based toolkit has been developed for the diagnosis of human African trypanosomiasis in humans and possibly animal reservoirs. This toolkit holds potential for One Health point-of-care diagnostics after test optimisation.[448]

Importantly, the added value of a One Health approach to diagnostics is relevant for not only infectious diseases, but also NCDs and environmental contaminants, such as pesticides and microplastics. In this context, animals sharing the same environment can serve as sentinels (as discussed in section 5).

Although laboratory services for humans and other animals have traditionally been separate, for historic, economic, infrastructural, and regulatory reasons, shared laboratory services also constitute a notable, integrated approach to multispecies diagnostics, especially with respect to rare, zoonotic diseases for which samples from humans and other animals need to be handled within the same biosafety level of containment. The Canadian Science Centre for Human and Animal Health was established more than 20 years ago as the first integrated biosafety level 4 laboratory, for purposes of studying the most threatening animal and human infectious agents and developing treatment and vaccines.[449,450] Shared diagnostic capacity might also be particularly valuable during health emergencies, as shown by the rapid conversion of veterinary laboratories into COVID-19 testing facilities, which greatly contributed to comprehensive testing in the early phase of the COVID-19 pandemic.[451]

6.2 A One Health approach to vaccines and medicines

A One Health approach to vaccines and medicines encompasses both preventive and curative interventions. This approach entails recognising the cross-species similarities that exist in the processes of developing vaccines and therapeutic agents, and exploiting the multispecies health benefits and cost savings of shared vaccines, shared medicines, and vaccinating animals against zoonotic diseases (thereby protecting the health of humans and other animals, as well as livelihoods). In most instances, preventive health interventions are more cost-effective than curative ones.[452] In the context of disease prevention, vaccines are among the most striking examples of having great One Health potential.

As early as the 1800s, cowpox was inoculated to humans to provide protection against smallpox.[453] More recently, a Rift Valley fever vaccine was developed for use in humans and livestock.[454] Although not yet tested in humans, this multispecies approach to vaccine development is expected to save time and money compared with developing separate vaccines for humans and other animals. In addition, universal vaccines can help to facilitate collaboration and resource sharing between the veterinary and public health sectors, including with respect to technological innovation.[455] In addition to a multispecies approach to vaccine development, the investment in animal vaccines for the control, prevention, and elimination of zoonotic diseases in both animals and humans is an exemplar of a cost-effective One Health approach. For example, high rabies vaccine coverage in dogs has been shown to be an affordable and highly effective intervention to prevent, control, and even eliminate dog-related human rabies in several countries.[456] Notable examples exist of a One Health approach to not only prophylactic vaccines, but also therapeutic agents. Ivermectin, for example, was developed as a veterinary antifilarial agent in 1981, was licensed for human use in 1987, and is now used extensively and effectively by mass drug administration programmes among humans that target filarial infections, such as onchocerciasis, lymphatic filariasis, scabies, and strongyloidiasis.[457]

The development of vaccines and therapeutic agents requires substantial investment. Although estimates differ, the research and development costs of a new medicine have been estimated to range from just less than US$1 billion to almost $3 billion, depending on the type of medicine.[458,459] Overall, research suggests that these research and development costs have been increasing over time.[458] Developing vaccines and medicines with multispecies applicability could accordingly allow for more cost-effective vaccine production by maximising returns on investment as a result of economies of scale. In addition to the needs for increased investment and cost-effective production based on economies of scale and market sizes, more equitable production and access to health products (particularly vaccines and medicines) are needed across geographical regions and socioeconomic strata. Currently, Africa depends almost exclusively, and unsustainably, on the rest of the world for its vaccines and medicines.[460]

6.3 A One Health approach to holistic interventions for health promotion, disease prevention, and disease management

Vaccines and medicines are two crucial forms of One Health interventions. A One Health approach to interventions is much broader, encompassing all other forms of action to advance health throughout the socioecological system. This action includes salutogenic approaches to fostering and sustaining mutually beneficial relationships between humans, other animals, plants, and the wider environment. For example, interacting with the natural environment has been associated with a range of human health benefits, including improvements in cardiovascular and mental health outcomes.[461,462] Research also shows a positive association between spending time in nature and pro-environmental behaviours, such as recycling and walking or cycling for short journeys.[463] These and other interventions that protect the environment both affirm the intrinsic value of the environment and ensure that it can continue to produce the healthy water, air, and soil that sustain humans, other animals, and plants. The environment also plays a role in the assembly of the human gut microbiota (as discussed in section 1).[99] Additionally, research suggests that environmental interventions can be of positive influence for antibiotic use and AMR across species. For example,

water, sanitation, and hygiene interventions and biosecurity measures among livestock and humans have been associated with a reduced need for antibiotic use (as discussed in section 4).[464]

A One Health approach can also be used to design integrated interventions that target several zoonoses in humans and animals simultaneously, making them especially cost-effective and thus more sustainable than potentially more costly unisectoral approaches.[465,466] This approach is especially important for controlling NTDs, which disproportionately affect populations that have insufficient access to essential services, including clean water and sanitation, and often rely on livestock for their livelihoods.[68] For example, an intervention in Laos that simultaneously targeted the zoonotic tapeworm (*Taenia solium*) and soil-transmitted helminths in humans and pigs, as well as the classical swine fever virus panzootic, proved far more cost-effective than programmes treating these diseases separately.[467,468] Importantly, behavioural and socioeconomic factors, such as sanitation, hygiene, and knowledge of transmission cycles between pigs and humans, were addressed alongside the biomedical intervention,[469] which can also have a positive effect on other diseases associated with poor sanitation, such as cholera.[177] This study underscores the importance of water, sanitation, and hygiene interventions, including the installation of toilets and latrines, that have an impact across multiple diseases, as well as the need for evaluations that show this impact.

A One Health approach to interventions can also be important for preventing and treating NCDs and for increasing wellbeing among humans and other animals, as humans and other animals often share the same environment, including its contaminants and pollutants. Any intervention that mitigates environmental contaminants and pollutants will logically improve health among humans, animals, and the ecosystem at large.[381] The same is true for lifestyle diseases, such as metabolic diseases, which affect health among humans and companion animals. As one example of a solution, joint physical exercise done by humans and their companion animals can prevent diseases and improve health for both. Other possibilities for shared NCD interventions are explored in sections 5.2 and 5.3.

A One Health approach to NCD interventions should also address plant health. Pronounced fungal growth on plants and crops, which causes diseases in plants, humans, and other animals, is an under-recognised and grossly neglected challenge in many low-income settings around the world. Mycotoxins cause crop destruction; milk, egg, and meat contamination; and organ damage, immunosuppression, and other health issues in humans and other animals. Environmental factors such as climate change, overcrowding, and insufficient sanitation and hygiene also play a role in plant health and fungal growth. A One Health approach to interventions for plant, human, and animal health includes, for example, pre-harvest and post-harvest interventions, detoxification strategies, in-house protective practices, and a One Health governance framework.[195,381] Due to the variety of factors that play a role on mycotoxin production, contamination will continue to vary across global regions due to the differences in regulatory measures and agricultural practices. This issue highlights the inter-relationships between food systems, agricultural practices, climate change, global trade, and veterinary and public health systems, and the necessity of a One Health approach to mitigate and prevent harmful health outcomes for plants, animals, humans, and societies—particularly in low-income economies, where the need for regulations is especially pronounced.

Importantly, no one-size-fits-all One Health approach to interventions exists. The health and economic benefits that can be expected from a One Health approach to interventions depend on, for example, the context in which the intervention will be implemented and the extent to which it is designed and implemented in context-specific ways. Both qualitative and quantitative social science research can generate insight into the social, cultural, economic, and political dynamics of local contexts and their relevance for designing and implementing interventions.[470,471] Qualitative research can also provide key information about local perceptions of and interactions with the environment and animals, as well as about the effect of these interactions on the welfare of humans, other animals, and the environment. For example, the aforementioned qualitative study conducted during the implementation of the joint intervention against pork tapeworm (*T solium*), soil-transmitted helminths, and classical swine fever in Laos explored the social, cultural, and behavioural factors that hindered and facilitated intervention compliance. Compliance rates with the mass drug administration regimen were high, possibly due to trust between health workers and community members established over 2 years of joint participation in the project.[469] If time and other resources are not invested in building trust with the community, however, factors such as misunderstandings of pharmacology, concerns regarding medication side-effects, and children's fear of intestinal worms might not be adequately addressed, which could potentially lead to decreased compliance.[472] Importantly, although compliance has conventionally been a focal point of One Health implementation research, participatory approaches to intervention design and implementation that shift the focus from community compliance to community partnership, in a truly transdisciplinary sense, provide especially valuable opportunities to engage local knowledge and resources, to align interventions with local priorities and sensitivities, and to ensure that interventions and their effects are optimised and sustainable.[473]

6.4 A One Health approach to health systems

The added value of a One Health approach to diagnostics, vaccines, medicines, and other interventions, coupled with the lessons learned from the COVID-19 pandemic (including the need for drastically strengthened health-systems resilience) call for a fundamental health-systems transformation. This transformation entails deep inclusivity, true partnership, and transdisciplinary processes of co-design and co-creation, with respect to civil society, within communities, and among vulnerable populations, including Indigenous populations. Working together is also needed across governmental ministries; public, private, and non-governmental and non-profit sectors; and civil societies and local communities, to achieve equitable, sustainable, and healthy socioecological systems.

In a One Health perspective, disease prevention and health promotion throughout the socioecological system must be on equal footing with curative medicine, and population-wide literacy in health and sustainability must be reached. This perspective presupposes that governments and human, veterinary, and environmental health authorities invest in creating and disseminating context-specific knowledge through a participatory approach.[474] Also needed are collaboration among physicians, veterinarians, human and veterinary public health experts, and experts on the health of the environment (ie, One Health practitioners) to advance health and sustainability, and a narrative that truly embraces a planetary and One Health perspective and addresses the broad spectrum health and sustainability challenges currently faced.[475] This perspective is fully aligned with the One Health ethos proposed by this Commission (panel 2) and the Geneva Charter for Well-being.[476]

The concept of One Health systems is nascent and underdeveloped.[477] The WHO health-systems building blocks put forward in 2007 aim to streamline health-systems strengthening and address service delivery, health workforce, health information systems, access to essential medicines, financing, and leadership and governance. Although anthropocentric in nature, these building blocks can guide the development of the concept of One Health systems.[478] In 2018, building blocks for One Health interventions were proposed in a World Bank report and share some similarities with the WHO health-systems building blocks. These building blocks address stakeholders, roles, and responsibility; financial and personnel resources; communication and information; technical infrastructure; and governance.[479] Although less anthropocentric and more aligned with the One Health approach and ethos, the Word Bank building blocks refer explicitly to human, animal, and environmental public health systems and their interfaces, and have been developed in the specific context of epidemic and pandemic prevention, detection, response, and recovery. However, the building blocks clearly point to the importance of the environment, which, together with the decarbonisation of health systems, also needs to be prioritised in the further development of the concept of One Health systems.[480] Additionally, future work around the concept of One Health systems needs to be linked to other ongoing endeavours, such as the universal health coverage agenda, which is committed to "building and strengthening equitable, resilient and sustainable health systems" and aligns well with the One Health approach.[481]

Concrete examples of what health care in a One Health system might entail can be drawn from primary health care, where health services targeting humans, animals, and the environment have been integrated successfully in some contexts. For example, a One Health clinic has emerged as an innovative health-care solution for underserved populations in Knights Landing, CA, USA. At this clinic, integrated human and animal health care has leveraged the human–animal bond and generated mutual benefits with regard to health-care access and disease prevention and treatment, including improvements to both physical and mental wellbeing.[482] Possibilities for integrating the environment into this clinic have also been suggested and indicators for the evaluation of performance have been proposed.[482–484] The purposeful collaboration of human and veterinary health professionals within communities and clinics could also play a crucial role in identifying emerging diseases and other health threats by using animals and humans as each other's sentinels. The interdisciplinary and transdisciplinary teaching and learning potential of combined clinics cannot be overestimated.

Undertaking a One Health-guided reconstruction of health systems depends on convincing governments and other stakeholders to do so. Therefore, key performance indicators showing One Health gains and financial savings are needed. A transformation of the global economic valuation system will also be required to allow for more equitable distribution of resources and full appreciation of the added value of the One Health approach, including with respect to mitigating climate change and biodiversity loss (as discussed in section 8.2).

6.5 Measuring the added value of a One Health approach

Ultimately, One Health aims to advance health and wellbeing throughout the socioecological system, through integrated, interdisciplinary, transdisciplinary, and multisectoral approaches that engage resources efficiently. Showing the added value of this approach is fundamental to increasing its adoption. As addressed in section 8.2, realising the One Health vision of equitable, sustainable, and healthy socioecological systems presupposes a fundamental shift in global economics.

Examples of One Health approaches that have generated added value in comparison with unisectoral approaches are currently available.[485,486] Investments in

strengthening veterinary and human public health systems in LMICs and reducing deforestation and biodiversity loss have been suggested to provide a net cost savings through pandemic prevention, with the 10-year cost of prevention representing only about 2% of that of the COVID-19 pandemic.[487] Despite these promising suggestions, reviews have indicated a paucity of standardised methods and metrics for the economic evaluation of One Health.[485,488] Development and standardisation of appropriate evaluation frameworks and decision-making tools are therefore urgently needed.

Despite the inherent complexity in evaluating multisectoral interventions, One Health aims to consider interventions from a societal perspective, and the body of literature on which to draw is growing. In table 1, we provide an overview of five key economic evaluation frameworks that are regularly used for guiding decision making and are of relevance for One Health. Underpinning these frameworks are methods for placing monetary and non-monetary values on investments and the consequences of a course of action. In tables 2 and 3, we review several of the key metrics relevant to the core One Health domains of people, animals, and the environment. The frameworks and metrics that we discuss include social progress indicators, such as redistribution, animal welfare, human wellbeing, and the protection and promotion of biodiversity and healthy environments, which relate to economic paradigms that centre equity, sustainability, and wellbeing.

As indicated in this section, several economic evaluation frameworks and decision-support tools might be suitable for expansion and uptake to robustly show the added value of One Health. However, most of these metrics prioritise human health. Metrics that equitably account for animals and the environment are needed. Appropriate and inclusive evaluation is integral to the successful implementation of One Health. In addition to quantitative indicators of success, such as reduced incidence of disease and the use of economic evaluation frameworks, other methods through which a One Health approach to interventions has been evaluated were identified through a 2022 scoping review.[229] A variety of evaluation frameworks were suggested. These frameworks focused on outcomes or process success and included a variety of quantitative or qualitative measures, such as changes in knowledge, attitudes, and practices, and One Healthness, as assessed by the Network for Evaluation of One Health. An alternative metric that has been suggested for measuring One Health performance across different One Health domains is the Global One Health Index, a metric based on a weighted inclusion of One Health indicators retrieved from authoritative, openly available data sources.[519] Global One Health Index scores vary considerably by region, with the highest scores attributed to countries in North America, Europe, and Oceania, and with countries in Africa obtaining the lowest scores.[519] Although whether this index will be taken up at scale remains to be seen, it simulates the

	Description
CEA	CEA is a comparison of costs and benefits where costs are expressed in monetary units and benefits are expressed in non-monetary units. The summary measure is the cost–effectiveness ratio, which can be compared with preset thresholds where available.[489] CEA is predominately used in health economics, with health benefits as the effectiveness measure.[490] CEA is also used beyond the health sector and for multisectoral analysis with a variety of effectiveness measures, such as those for inequality or environmental outcomes.[491,492]
Social CBA	CBA is a comparison of costs and benefits expressed in monetary units to give a summary measure of net present value. Social CBA is an extension of CBA to account for social and environmental outcomes.[493] Where no market value is available for a particular good or service, shadow pricing techniques (placing a hypothetical value on a non-market good or service) can be used to provide a contextually appropriate value. Social CBA is a highly flexible framework, but value judgements in monetisation must be explicit and can be highly context specific. CBA is currently rejected by health technology assessment agencies in some countries (eg, the UK, France, and Germany) due to ethical concerns about placing a monetary value on human health.[490,494,495]
Social LCA	LCA is an assessment of environmental impacts associated with all stages of the life cycle of a product, process, or service.[496] LCA can be expanded to account for the actual and potential positive and negative social impact of these goods or services across the life cycle (social LCA).[497] Comparisons of environmental impact inventory, quantified in natural units of a good or service, can reveal the good or service with the least environmental impact. Methodologies also exist for monetising the impact inventory to generate a monetised LCA.[498] Monetised LCAs have similarities with CBA, though methodological differences exist (eg, non-use of discounting within LCAs and removing some of the methodological criticisms that environmental economists hold with CBA for discounting future benefits).
MCDA	MCDA is a systematic approach to complex decision making that is highly adaptable to multisector considerations.[499] Costs and benefits are described in non-monetary units, with stakeholder weightings applied. A variety of methodologies for MCDA exist (eg, analytic hierarchy process, multiattribute utility theory, outranking, and order of preference by similarity to the ideal solution). Non-monetised LCA has several similarities with MCDA methodologies, but the two frameworks have also been applied together, with MCDA being used to develop LCA, and MCDA being used to allow better interpretation of LCA outputs by decision makers.[500]
SD modelling	SD modelling is a highly flexible modelling process to understand complex systems based on the flow of resources through a system over time and with integration of feedback loops between compartments. The system of interest can be conceptualised as a causal loop diagram using a participatory group model-building process. The resulting model can qualitatively describe complex systems. Computer-aided simulation is then used to run the model for quantitative outputs to which monetary values can be assigned, making it possible to simulate data to integrate with CEA or CBA.[501]

CBA=cost–benefit analysis. CEA=cost-effectiveness analysis. LCA=life cycle assessment. MCDA=multi-criteria decision analysis. SD=system dynamics.

Table 1: **Key economic evaluation and decision support frameworks relevant to One Health**

	Description
Life-years gained	Life-years gained is a simple unidimensional metric for health improvement that considers changes in mortality only, with no quality-of-life dimension.[502]
QALY	A QALY is a composite metric accounting for the quantity and quality of life, and is the leading metric for quantifying health gains in health technology assessments. Health-related quality of life is measured on a scale of 0–1 and is linked to health rather than disease states. QALYs are considered a good to be maximised. The assessment of health-related quality of life is challenging, but methodologies include time trade-off and standard gamble, in which individuals make explicit choices regarding what they would sacrifice in terms of time or risk of death to return to a state of perfect health, as well as indirect measures, such as the use of the EQ5D.[503] Ethical concerns have been raised regarding the possibility that the lives of people with disabilities are inherently devalued by the QALY system. A treatment that extends the life of people with a lower health-related quality-of-life score will result in fewer QALYs gained than one that extends the life of people living with higher subjective quality-of-life scores.[504]
DALY	One of the most frequently used metrics in global health policy planning, DALYs estimate the gap between a population's current and optimal health. DALYs are considered a bad to be minimised. A DALY is a composite metric considering years of life lost and years of life lived with disability, assessed through disability weighting, on a scale of 0–1. Multiple methodological updates have been made to the DALY since its introduction in 1993.[505] The DALY is currently used by the Institute of Health Metrics and Evaluation to measure the global burden of 369 diseases and injuries in 204 countries and territories on an annual basis within the Global Burden of Diseases Study.[506] Standardised methods for DALY calculations with supporting models are available.[507] Disability weightings remain one of the most contentious aspects of the DALY and, like the health-related quality of life measure, have been derived from patient, expert, and community surveys using instruments such as time trade-off and standard gamble.
HALY	A group of newly proposed, enhanced HALY metrics in which the multiattribute surveys used to measure health or disease states are extended to incorporate human wellbeing. Examples include the wellbeing-adjusted life-year[508] and the capability-adjusted life-year.[509] These extensions can be produced through the use of bolt-on measures within survey tools such as the EQ5D or by developing new tools to measure broad societal outcomes, rather than health states. Although extensions to the core HALY metrics (DALYs and QALYs) are not in common use, the body of literature considering their use in economic evaluation frameworks from the societal perspective is expanding.
zDALY	The zDALY is an expansion of the DALY that incorporates an animal loss equivalent, which converts economic losses suffered in livestock into DALYs by dividing the monetary value of the loss by the national income to reflect the time a person would spend recouping the loss (eg, a loss of $500 in a country where the GNI is $1000 would be equivalent to 0·5 DALYs).[510] The principle of the zDALY is simple to apply and could enable other environmental and social impacts to be incorporated into a single metric, based on the relationship between the market-based economic losses and GNI, or by using an intermediary step of assigning a proxy monetary value to a non-market good or service and then dividing by the GNI.
WALY	A novel metric proposed to measure animal health impact similar to the DALY for humans, the WALY combines the years of life lived in impaired welfare and the years (or potentially months) of life lost from premature death, with the expected life expectancy appropriately optimised to reflect the role of the animal species in human society (ie, the role as a companion or food-producing animal).[511] Although the WALY is potentially useful in prioritisation exercises for animal health issues and for cost-effectiveness analysis within the animal health sector, the use in multisectoral analysis would depend on the availability of a mechanism to appropriately weight the WALY in comparison with a DALY, in order to combine the two into a single measure of outcome. Alternative metrics to incorporate animal welfare indicators include species-adjusted measure of suffering-years.[512]
Morally adjusted animal lives	Morally adjusted animal lives incorporate life quality and a subjective weighting for moral value on the basis of perceived intelligence in comparison with that of humans, which, in theory, might provide a mechanism to allow comparison of morally adjusted animal lives avoided to DALYs avoided.[513] The moral implications of using perceived intelligence as a rationale for weighting the value of a saved life needs more investigation.
Lifecycle impact assessment categories	Integral to the lifecycle impact assessment are multiple impact categories, measured as midpoint or endpoint indicators, which result in a damage indicator (to human health, ecosystem quality, resources, and ecosystem services). Each impact category has specific metrics for reporting (eg, climate change due to greenhouse gas emissions is expressed in kilogram CO_2 equivalents, ozone depletion in kilogram trichlorofluoromethane equivalents, and freshwater contamination with nutritional elements such as nitrogen-containing or phosphor-containing compounds in kilogram nitrogen equivalents and phosphor equivalents).[514,515]
World Happiness Report	The World Happiness Report is an annual publication that uses data based on the Gallup World Poll, such as the Cantril Self-Anchoring Striving Scale (or the Cantril Ladder), to showcase global happiness rankings of countries worldwide. The Gallup World Poll is a survey done every year in more than 100 countries and includes life satisfaction ratings and emotional wellbeing questions. Gallup data is used extensively in multiple global datasets.[516–518] Many other efforts to report national and global wellbeing measures exist, such as the Organisation for Economic Cooperation and Development Better Life Index and the Happy Planet Index.[518]
GOHI	The GOHI, proposed by Zhang and colleagues[519] in 2022 is a composite metric comprising three indexes of indicators drawn from open-source data from over 200 nations and weighted by a panel of experts. The three indices of indictors are intended to enable a holistic and context-applicable assessment encompassing One Health implementation across a range of key challenge areas, including zoonotic diseases, AMR, food security, climate change, and governance (ie, the core drivers index); social, economic, and cultural facilitators of One Health (ie, the external drivers index); and the integration of human–animal–environment systems (ie, the intrinsic drivers index).[519] Given the holistic nature of One Health, the GOHI has similarities to other multi-indicator composite metrics proposed for the evaluation of societal progress beyond gross domestic product, such as the Social Progress Index.[520]

DALY=disability-adjusted life-year. EQ5D=EuroQoL-5 Dimension scale. GNI=gross national per-capita income. GOHI=Global One Health Index. HALY=health-adjusted life-year. QALY=quality-adjusted life-year. WALY=welfare-adjusted life-year. zDALY=zoonoses disability-adjusted life-year.

Table 2: **Non-monetary metrics relevant to One Health evaluation frameworks**

conversation around the incorporation of One Health-appropriate indicators within the measurement of societal progress.

The paucity of standardised evaluation frameworks currently limits the empirical evidence for the added value of the One Health approach to diagnostics,

	Description
VSL	VSL is one of the most important and regularly used parameters for including health in economic evaluations. It is a measure of a population's WTP* for a small reduction in risk of mortality or willingness to accept compensation (in the form of higher wages) for an increase in mortality risk.[521] VSL does not account for the social value of lives lost (eg, the loss of social capital or grief experienced by society). The VSLY can be estimated by dividing the VSL by the expected number of remaining years of life. The VSLY has been used by some researchers as a proxy for the monetary value of a Disability Adjusted Life Year (DALY), in order to create a combined monetary burden of disease.[522]
Monetised value of a DALY or QALY: public sector-implied WTP	Public sector-implied WTP is a relative value of outcomes implied by the allocation of public-sector resources to an outcome cost per QALY threshold. More research is required to determine thresholds for different outcomes in different sectors. Implied values could be used as the monetary value in cost–benefit analysis or monetised lifecycle assessment frameworks. Public sector-implied WTP assumes that the public sector allocation is efficient and reflects the values placed by the public on the outcome.[508]
Monetised value of a DALY or QALY: individual WTP (welfarist)	Multiple methodologies (such as QALY or DALY) are available to value a health outcome from a welfarist approach.[523] Concerns arise from the valuation of health outcomes by individuals, particularly related to variations due to income inequality. Therefore, the WTP should be corrected for income inequality through the application of distributional weights.
Monetised value of a DALY or QALY: societal WTP (non-welfarist)	To overcome arguments against both public sector-implied and welfarist WTP methodologies, a non-welfarist approach would consider asking members of the public what a government should provide towards different policies and sectors. As payment is not out of pocket, distributional concerns are reduced compared with out-of-pocket expenditure schemes and income inequality should not affect the WTP.[524] For economic evaluations from a societal perspective, such societal non-welfarist approaches would be most appropriate.
Cost-of-illness studies	Cost of illness refers to a descriptive assessment of the economic burden of health problems from a patient, health provider, or societal perspective, into which the direct and indict costs of illness are combined with morbidity-related and mortality-related production losses. Monetary valuations of lives or QALYs lost are sometimes incorporated into cost-of-illness studies.[525]
Monetised lifecycle impact assessment categories	The monetisation of lifecycle impact assessment categories for use in cost–benefit analysis or monetised lifecycle assessment includes a diverse range of approaches, such as observed and revealed WTP from real and surrogate markets, damage costs (ie, the costs incurred due to direct environmental impacts, such as the health impact of air pollution), and abatement costs (ie, the costs incurred per unit of good or service under the condition of low or no environmental externality, such as the additional cost per unit of electricity produced with low-emission technology). The methodologies for the valuation of environmental indicators have been extensively reviewed.[526,527]
Natural capital accounting	Natural capital accounting identifies the stocks, condition, and flow of natural assets and the services they generate over time, including their depreciation. Although often anthropocentric in nature, value can be attributed to natural assets in their own right, allowing nations to account for their natural capital reserves and the depreciation of such reserves within their conventional national accounts.[528]
GPI	GPI is a measure of national wellbeing that accounts for personal consumption expenditures, adjusted for factors such as income inequality, environmental costs, and other positive and negative social outcomes.[529] Methods for accounting for non-monetary goods and services, used in the calculation of GPI, might be of interest in the development of improved social cost–benefit analysis frameworks.
Economic losses from animal diseases	The valuation of losses due to animal disease and the response to these diseases are generally assessed through the market prices of the goods and services these animals provide. Standardised guidelines for the conduct and reporting of animal disease burden studies are not yet available, which makes comparing studies difficult, as shown by a 2022 systematic review of economic evaluations for foot and mouth disease.[530] Progress towards a systematic methodology for determining the societal burden of animal diseases is being led by the Global Burden of Animal Diseases consortium using the concept of the Animal Health Loss Envelope, representing the gap between the operation of a production system under perfect conditions and in the presence of hazards (eg, disease or injury).[531]

GPI=genuine progress indicator. VSL=value of statistical life. VSLY=value of a statistical life-year. WTP=willingness to pay. *The WTP approaches comprise a variety of methodologies, including discrete choice experiment, constant sum paired comparisons, contingent valuation, hedonic pricing, and others.[524,532] Ethical concerns have been raised over the use of WTP methods in the health sector.[533]

Table 3: **Monetised valuation methodologies**

vaccines, medicines, and other interventions. As a nascent discipline, One Health economics must consolidate knowledge and practice and engage decision makers to obtain consensus on guiding principles and methodological consistency. Key priorities for the discipline include assessing which frameworks and metrics to use across sectors and how to report complex evaluations transparently and accessibly. Additionally, novel approaches to cost sharing and funding should be considered in order to better reflect the attribution of costs and benefits within multisectoral interventions.[534–536] Despite a societal perspective being the best fit for One Health economics, translating a multifactored societal outcome or net societal benefit into sector specific systems with their own budget lines and interests is difficult. Suggestions to better align decision-making processes with societal goals include interministerial platforms and central One Health offices positioned at the highest levels of government.[537] Developing these integrated mechanisms requires time and other resources, and presupposes that current resource imbalances between the human, animal, and environment sectors are addressed.[69,485]

Ministries of health and agriculture tend to have different and potentially conflicting priorities in their approaches to disease management, with few institutional

mechanisms or legal frameworks currently supporting collaboration and a potential reluctance to fund issues that each ministry believes is the responsibility of the other.[538] For example, the economic costs and benefits of rabies control are unevenly distributed across sectors; although the human public health sector retains most of the economic benefit, including reduced human rabies cases and avoided expenditure for post-exposure prophylaxis, the veterinary sector is generally responsible for the costs of canine rabies control but receives few financial returns, as dogs are not considered an economically valuable species.[539] Seen from a societal perspective, the cumulative cost of mass vaccination of dogs at sufficiently high coverage to interrupt transmission is lower than continuous human post-exposure prophylaxis,[540] yet costs and benefits are attributed differently in different ministries, with logistical difficulties for efficient cost sharing. A solution to the appropriate attribution dilemma has been seen in Latin America, where all canine rabies control responsibilities have been brought under the remit of the ministries of health,[541] but for more complex interventions, alternative solutions must still be explored.

In conclusion, despite the complexities and challenges associated with evaluating the One Health approach to interventions, several prominent examples have clearly shown the added value that this integrated approach can yield. Given the vast breadth of instances in which a One Health approach can be engaged, a balance must be struck between the aim of economically evidenced added value and the need to assume impact pathways that prevent disease, avoid harm, and apply resources efficiently and equitably. Greater attention should also be paid to the challenges of scaling up what are commonly small-scale research projects, including properly piloting and adjusting them for wider (eg, national or regional) implementation. Additionally, given that research has predominantly focused on zoonotic infectious pathogens, increased knowledge is needed regarding the potential added value of a One Health approach to NCDs and environmental protection. A synthesis of key messages and gaps related to One Health, health-promoting synerties, and health systems is presented in the appendix (p 6).

7. A One Health approach to equitable, sustainable, and healthy food systems

7.1 Introducing a One Health perspective on food systems

Food systems encompass all actors and activities involved in all stages of food production, processing, distribution, consumption, and disposal (figure 8). Food systems span agriculture, fishing, and forestry and operate at local, national, regional, and global levels. Food systems activities and outcomes are influenced by multiple forces (ie, drivers), including politics, economics, culture, commercial interests, demographics, consumption trends, and research and development. Desirable food systems outcomes can include food security and the promotion of sustainable and healthy diets, as well as income generation, improved livelihoods, and economic development.[542]

Accounting for food systems interests among the multitude of actors and drivers requires a balancing act, at the heart of which are interdependent relationships between humans, animals, plants, and the wider environment. Of utmost importance from a One Health perspective is the question of how to sustainably and equitably meet the food and nutrition needs of a growing, more affluent, and socially dynamic human population, while promoting the health and wellbeing of humans, other animals, plants, and the environment at large. One Health and the principles of holism and systems thinking, epistemological pluralism, equity and egalitarianism, and stewardship and sustainability (panel 2) can help us to negotiate this question and to address the global health challenges of malnutrition and food insecurity, as well as the sustainability challenges of contemporary food systems, in ways that centre equity, prioritise sustainability, and advance health throughout the socioecological system.

7.2 Interconnected food systems challenges

Food systems are largely extractive and destructive, reinforcing inequities and generating and perpetuating an unsustainable, unsafe, and unhealthy range of environmental, health, and socioeconomic costs linked to food. These costs (nearly US$12 trillion annually) exceed the value of the global food systems output.[543] Achieving equitable, sustainable, and healthy food systems entails addressing several crucial challenges: foodborne diseases, undernutrition and overnutrition, and unsustainable trends in agrifood systems.

7.2.1 Foodborne diseases

Animal agriculture, transport, slaughter, processing, and packaging are all activities that risk the exchange of pathogens between live animals and workers, as well as the contamination of food products,[544,545] rendering food systems key sites of zoonotic and foodborne disease emergence. An estimate of global foodborne disease incidence, mortality, and DALY burden in 2010 reported that diarrhoeal agents are a major cause of global mortality and that 33 million DALYs are lost to foodborne diseases, primarily among children younger than 5 years and populations in low-income settings.[546] The associated productivity losses are estimated at US$95·2 billion per year in LMICs alone.[547] Additionally, antimicrobials are used to promote growth and prevent and treat infections in food-producing animals and plant agriculture. Antimicrobials are at times also added to food products as preservatives.[548] Both scenarios could have implications for AMR (as discussed in section 4).

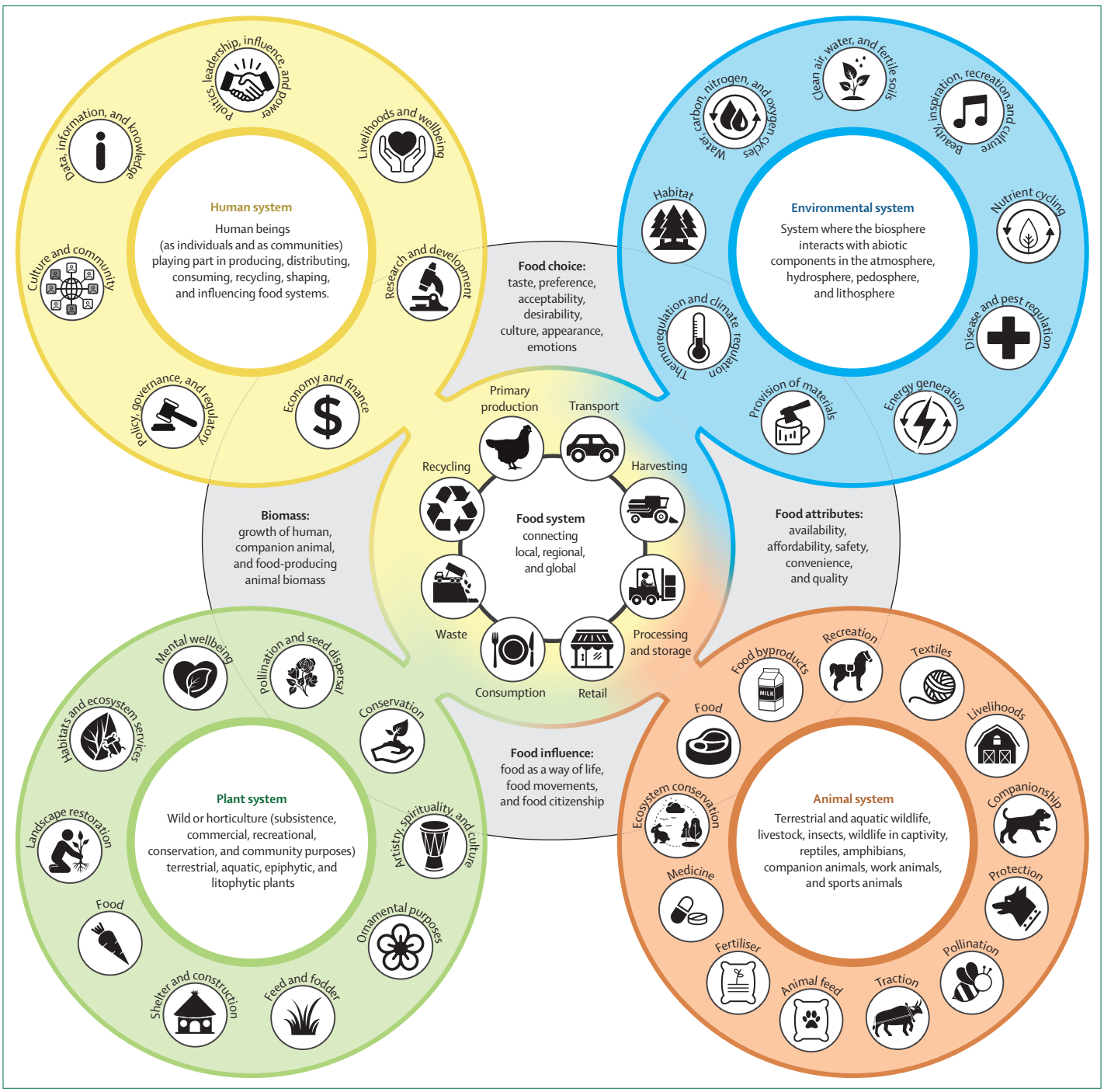

Figure 8: **The food system**
At the heart of food systems are interdependent relationships between humans, other animals, plants, and the wider environment. The One Health approach is crucial for addressing the health and sustainability challenges that arise in connection with contemporary food systems, and for advancing equitable, sustainable, and healthy food systems.

Within the formal, regulated food system, international food standards, guidelines, and codes of practice contribute to safety, quality, and fairness in the international food trade.[549] However, a considerable proportion of the global population is fed through informal food systems. These systems generate income and autonomy with respect to food production, distribution, and purchase, often with varying degrees of locally defined rules and practices, but without subscribing to formalised and internationally regulated

standards.[550] Food safety and animal welfare concerns arise in particular around the wild animal trade and markets,[551,552] which, despite risks, play a crucial role in food security, cultural expression, social cohesion, dietary diversity, and livelihoods of billions of producers, sellers, and consumers around the world.[553] A major barrier to safer food production and exchange in the informal food sector is the insufficient infrastructure required to promote and enable sufficient hygiene among producers and market stakeholders.[554] Hygiene-promoting incentives, which have been shown to be more effective in delivering safe food than enforcement and penalties, are inadequate.[547,555,556] The role of trade liberalisation might also be important to consider, along with potential differences in risk between the international wild animal trade and domestic trade and markets.

7.2.2 Undernutrition and overnutrition

Both undernutrition, resulting from hunger and food insecurity, and overnutrition, resulting in obesity, are increasing globally.[557] In the past 30 years, a transition has occurred in global nutrition from primary foods to processed and ultra-processed foods with low fibre content and high amounts of salt, fat, and sugar. The ten leading multinational food and beverage companies of the world produce and actively market mostly ultra-processed foods,[558] which now make up more than half of the total energy intake in HICs and a rapidly growing proportion in middle-income countries, where marketing is increasingly focused.[559] Trade liberalisation, increased foreign direct investment in and financialisation of the food sector, and pervasive and aggressive promotion of ultra-processed foods and unhealthy eating habits all make highly processed and unhealthy foods widely available and affordable on domestic markets, which undermines public health.[560] The triple burden of undernutrition, overnutrition, and micronutrient deficiency (which are all risk factors for NCDs) is rising rapidly, including among urban populations with low income.[561–564] The global rise in obesity among both adults and children is so intractable that the 2025 WHO target for childhood overweight is merely to stop the increase,[565] and even this target has been shown to be substantially off track and unlikely to be reached.[566,567]

7.2.3 Unsustainable trends in agrifood systems

Food waste is a notable unsustainable trend. An estimated one third of all food produced globally for human consumption (1·3 billion metric tonnes) goes to waste each year.[568] In 2018, 2 billion people (approximately a quarter of the world's population) faced moderate or severe food insecurity (ie, lacked regular access to a nutrient-dense and sufficient food supply), and more than 10% of the global population was undernourished.[569] Reducing food loss and waste and increasing the efficiency of global trade, including through more equitable food distribution, would help to mediate the socioeconomic drivers of food insecurity, such as poverty and inequity.

GHG emissions and encroachment are also unsustainable. The global agriculture sector, forestry, and other land use are estimated to account for 23% of global GHG emissions.[570] Evidence overwhelmingly supports that reducing animal agriculture and supporting carbon-neutral agricultural production systems are major keys to substantial reduction of GHG emissions.[571–575] The loss of wildlife habitat to pasture and farmland is a major risk factor for infectious disease outbreaks, including pandemics.[576,577]

Lastly, monocultures need to be addressed. Given the increasing food demands of the growing global population, monocultures of crops such as rice, corn, soya, and wheat have increased to maximise efficient use of soil and local climate, crop yield, and profit. However, monocultures have considerable environmental impacts, including increased use of pesticides and fertiliser, soil degradation, and decreased biodiversity.[578,579] Similarly, the increasing demand for meat and the promotion of enhanced livestock breeding practices have implications for animal welfare and are contributing to poor genetic diversity among herds, which potentially increases susceptibility to pathogens.[483,580]

7.3 One Health for food systems understanding and transformation

Systemic changes towards more sustainable agriculture and food consumption are urgently needed. Any transformation must recognise that the importance of livestock and other animals in many countries and cultures extends beyond their contribution to diets, and might include their roles in providing agricultural traction and facilitating mobility, their social values as companion animals, and their cultural or spiritual significance.[581] The maldistribution of power within food systems, the dynamics of food systems globalisation and financialisation, and implications for sustainability and health throughout the socioecological system also need to be addressed. Global food systems are exceptionally interconnected, with complicated trade networks focused on supply chain efficiency.[582] However, some food systems concentrate power in a few hands and locations, thereby reducing resilience against shocks. This reduced resilience manifests as food shortages, as recently seen with the COVID-19 pandemic and the Russia–Ukraine war.[583–585] Considering how a financialised global food production system that feeds the world might also result in the erosion of public goods (including a negative effect on climate and biodiversity), the often conflicting narratives between the public and private become clear and need to be addressed (panel 6).

One Health can help us understand and navigate the complexity of food systems challenges, identify and

cultivate unifying values around various stakeholders' roles and responsibilities, and ultimately implement changes that contribute to sustainable food systems (ie, to deliver food safety and security in globally, intragenerationally, and intergenerationally equitable ways and promote the health and wellbeing of humans, other animals, plants, and the environment at large).[596]

To operationalise a One Health approach to food systems, a holistic, global food systems governance platform and financing framework is needed. Through this framework, international and collective action to improve food systems should be prioritised, funded, monitored, and overseen, and non-compliance with agreed food safety, food quality, animal health and welfare, and environmental standards should be penalised. In addition, One Health competencies and food systems literacy that holistically address interconnected food systems challenges are needed among non-governmental actors, including donors, regional governance bodies, civil society, and non-governmental organisations.

Of particular importance to sustainable food systems is optimising the affordable production of safe and nutritious food, while simultaneously supporting livelihoods and maintaining public goods, such as ecosystem services, reduced GHG emissions, and healthy human and animal populations. This goal is just as important in aquatic systems as in terrestrial systems and, although aquatic systems are often under-considered in the One Health field, a One Health framework can help increase the productivity of aquatic food systems and ensure sustainability.[597]

To drive cohesive policy dialogue around food systems and to address the complex, inter-related issues emerging in the human health, animal health, plant health, and environmental fields, considerations of power dynamics and variations in value systems among a broad range of stakeholders are crucial. The political economy perspective challenges the more traditional, productivist approach to food security, which encourages a focus on food sufficiency at the expense of food safety, nutrition, and sustainability.[598–600] Applying a political economy perspective brings to the fore the use of the One Health approach in providing an opportunity to re-examine specific regional or national priorities and to share lessons and other complementarities both

Panel 6: The financialisation of food systems

Financialisation generally refers to the increasing importance of financial markets, motives, institutions, and elites in the operation of the economy and its governing institutions.[586,587] Financialisation has been transforming how and which food is produced, distributed, and consumed, sometimes compromising the capacity of food systems to provide long-term livelihoods and food security. For example, financialisation can result in changing priorities, as maximising dividends for shareholders becomes paramount and might entail bundling services with insurance products for hedging against risks, which shifts responsibility from the state to farmers.[588] Changes in food production priorities motivated by financial incentives might worsen existing power and wealth imbalances, and could lead to corporate consolidation with concentrated power, decreased farming diversity and biodiversity, dependence on insurance products, externalisation of environmental and social costs, and price volatility (which risks extreme food price increases and consequently hunger).[588] An example of the complexity of the problems associated with the financialisation of food systems and the implications for food security is the year-long protests by farmers in India that ended in November, 2021 relating to new laws that they feared would bind contractual farming to corporate buyers and thus create monopolies in the grain markets. Farmers wanted to maintain their autonomy as cultivators and the Indian government eventually conceded.[589,590]

Serious food security and environmental impact concerns exist regarding investors buying swathes of arable land for surface mining (after which only non-arable wasteland remains)[591] and acres of pristine forest for cash-crop farming, such as banana and palm plantations.[592] Researchers and the media have also raised alarm about heightened farmland investment in Africa, Asia, Latin America, and central Europe, particularly regarding the influence of private investors in global agrifood value chains and the consequences of their actions, which include the loss of land for subsistence farming and the promotion of cheap and calorie-rich, unhealthy foods.[593] In the past 10 years, investments in meat and dairy corporations have attracted renewed scrutiny. Between 2015 and 2020, more than US$478 billion was invested in meat and dairy companies from more than 2500 investment firms, banks, and pension funds globally.[594] A 2020 report by FAIRR Initiative shows that meat sector companies are acting insufficiently to measure and manage pandemic risk across seven selected environmental, social, and governance (ESG) risk and opportunity factors: deforestation and biodiversity loss, antibiotics, waste and pollution, animal welfare, working conditions, food safety, and sustainable proteins.[595] The majority of companies included in the study (44 [73%] of 60, which are together valued at $224 billion) were considered high-risk, and more than three-quarters of these 60 companies were categorised as such due to the following three ESG risk factors: waste and pollution (94%), deforestation and biodiversity (88%), and antibiotics (77%).[595] Nevertheless, the negative environmental effects of these systems are often ignored and investors routinely tout sustainability policies.[594] Without public disclosure of ESG performance and management by companies, investors will remain unable to accurately assess the health and sustainability risk that these companies introduce into food systems.

Panel 7: **Exemplifying a One Health approach to the political economy of food systems**

In this example, Country A is grappling with groundwater contamination as a national environmental policy issue, and is also concerned about high concentrations of antibiotic residues in imported poultry from neighbouring Country B. Groundwater and food safety are mandated by two separate policy bodies in Country A. In Country B, the sale of antibiotics is a key livelihoods option for animal health providers acting within a largely privatised veterinary system. Despite these seemingly different and unrelated issues, a political economy approach, when applied through a One Health lens, could help to identify common ground that facilitates joint approaches to identifying and funding solutions.

Countries A and B endorse a new regional policy to promote agricultural chemical best practice, catalysing both public and private regional agricultural value chain actors to agree on acceptable frameworks for the registration, distribution, and monitoring of agricultural inputs (including animal therapeutics). For Country A, this regional policy helps catalyse increased national investment and support to address groundwater contamination. This policy will also help support Country A's standards around maximum accepted residue limits for imported poultry, with the desired positive effect on national food safety.

For Country B, this new regional agricultural chemical policy catalyses national policy dialogue around incentives for private agricultural value chain actors, including veterinary paraprofessionals, to help encourage lower concentrations of chemical residues in plant and animal products. With the right domestic policy settings, this policy might even result in increased benefits to the producer for improved food safety compliance, resulting in better quality and higher value poultry exports.

In this way, looking holistically at food systems challenges can help identify synergies between the public health, agricultural, and environmental sectors, including the public and private actors within them, to facilitate improved health, welfare, and environmental sustainability and support the private-sector interests that are central to food production and supply.

between countries and regions and internationally, as exemplified in panel 7.

The EAT–*Lancet* Commission on healthy diets from sustainable food systems identified food as the strongest lever for positive planetary change. The Commission warned, however, that "global food production threatens climate stability and ecosystem resilience. It constitutes the single largest driver of environmental degradation and transgression of planetary boundaries".[601] We support the EAT–*Lancet* Commission's call for food systems that, among other things, reduce food loss and waste by half, and we underscore the need for more explicit assessment of the health of humans, other animals (including insects), plants, and soil in food research, decisions, and policy making. To drive cohesive policy dialogue around food systems and to address the complex and inter-related health and sustainability challenges in which food systems are implicated, the One Health priorities of food systems must be understood and articulated locally, nationally, regionally, and globally. Crucially, regionally sensitive approaches are necessary, especially to understand the effect of local livestock production for food. Although global consensus is needed, a one-size-fits-all approach cannot be taken.

As this discussion has outlined, the complexity of global food systems and the quest for balanced and healthier outcomes among all humans and throughout the socioecological system underscores the potential of a One Health approach for transforming food systems. Identifying sustainable solutions to food systems challenges requires the application of current concepts, knowledge, and tools across a broad range of technical, economic, social, and political dimensions and satisfying a multitude of actors and drivers. Given that basic sufficiency goals are not on track to be met, and knowing well the negative impacts of current food systems on public health, animal wellbeing, and the environment, contemporary food systems clearly require a One Health-guided recalibration. A One Health approach to food systems becomes even more important in countries where agricultural production is a key contributor to livelihoods and incomes among rural populations with low income[602] and where business as usual would result in more negative impacts on the world's most vulnerable communities. In this way, the challenge of sustaining the fundamental functions of global food systems, including food security and safety, nutrition, livelihoods, social security, and economic development, while minimising the negative impacts on global public goods, such as climate stability, natural resources, ecosystem services, biodiversity, and public health, remains a One Health priority. A synthesis of key messages and gaps related to One Health and food systems is presented in the appendix (p 7).

8. A socioecological transformation for the 21st century and beyond: avenues for One Health operationalisation, implementation, and institutionalisation

In this Commission, we have synthesised and appraised the One Health state of the art, from a socioecological perspective and in the contexts of key health and sustainability challenges (including the triple planetary crisis of climate change, biodiversity loss, and pollution), infectious diseases (endemic, epidemic, and emerging), NCDs, and AMR. In addition, we have addressed a One Health approach to surveillance; food systems; and

diagnostics, interventions, and health systems. In this final section, we propose three equally crucial, intersecting, and interdependent avenues for One Health operationalisation (ie, translation of the One Health concept into action), implementation (ie, execution of relevant actions), and institutionalisation (ie, integration as a normative way of operating), to guide the transformations in governance, economics, and knowledge that are necessary to achieve equitable, sustainable, and healthy socioecological systems.

8.1 One Health governance

Governance processes are varied, complex, and dynamic. Multiple actors, scales, and timeframes are involved.[603] Contemporary literature distinguishes two forms of global health governance: global governance of health, referring to governance of and within the health sector, and global governance for health, referring to governance that serves the interests of health throughout all relevant sectors.[604] Global governance for health has focused on the social and, to some extent, environmental determinants of health and the political drivers of health inequity, alongside which promoting health and achieving health equity has come to be understood as the shared responsibility of all sectors.[605–607] Governance of and for One Health also requires multisectoral investment in and shared accountability for human, animal, and environmental wellbeing. Building on calls for Health in All Policies and whole-of-government and whole-of-society approaches to global governance for health,[608,609] this Commission calls for an approach to governance that can be conceived of as One Health in All Policies, across all sectors, and at all levels of society.

8.1.1 One Health governance advances and challenges

Advances in One Health governance have included many high-level endorsements of One Health; global moves towards concrete frameworks for One Health operationalisation, implementation, and institutionalisation;[13,51,68,69,174,610–618] declarations of One Health principles (panel 2);[46,49] and the proliferation of international, national, regional, and institutional One Health platforms, networks, alliances, and coalitions.[619,620] The establishment of the One Health Quadripartite and the OHHLEP,[621] the widely adopted OHHLEP definition of One Health, and the October, 2022 launch of the 5-year One Health Joint Plan of Action,[174,622] have been especially important steps on the path towards growing consensus and joint One Health governance. Several national One Health strategic action plans have also been adopted,[618] especially in LMICs and in some cases with the support of development cooperation and assistance.[623] Almost 100 countries have One Health action plans on AMR.[624]

Despite this progress, governance challenges remain substantial. NCDs have received little to no attention in One Health action plans, and global action plans on NCDs seldom engage the One Health approach despite its relevance.[625,626] Moreover, several countries, and HICs in particular, lack the legal frameworks, strategies, and structures needed to support and advance multisectoral collaboration towards One Health operationalisation, implementation, and institutionalisation.[13]

One Health governance has also been stymied by insufficient harmonisation and coordination among initiatives and by fragmentation, including competition among stakeholders, systems, and sectors with varied principles, norms, regulations, power, and priorities.[627] Challenges also exist regarding the investments needed for One Health-guided pandemic prevention, which the World Bank estimates amount to US$10·3 billion to $11·5 billion per year (ie, far less than the cost of managing a pandemic, but nevertheless substantial).[628]

These challenges to One Health governance are exacerbated by donor-driven development agendas, short-term and sector-specific funding, competition between organisations and ministries, and elite capture (ie, when public resources and policies protect the interests of powerful elites). In-depth understanding of sector-specific priorities, incentives, organisational cultures, and spheres of influence, and especially of the complementary and overlapping interests and co-benefits of collaboration, is fundamental for generating a sense of shared responsibility for achieving and sustaining healthy socioecological systems and the strong commitment to the transformations demanded across all sectors and stakeholders. The IPBES assessments on the links between biodiversity, water, food, and health,[629] the underlying causes of biodiversity loss, determinants of transformative change, and options for achieving the 2050 vision for biodiversity,[630] show progress, as does the UNEP blueprint for jointly addressing the triple planetary crisis of climate change, biodiversity loss, and pollution.[631] Other insights could be generated by examining how the challenges to collaboration and decision making across multiple sectors, scales, and global regions were confronted in the development of climate change governance,[632] and in establishing the Agreement under the UN Convention on the Law of the Sea on the Conservation and Sustainable Use of Marine Biological Diversity of Areas beyond National Jurisdiction.[633]

8.1.2 Towards achieving governance for One Health

One Health operationalisation, implementation, and institutionalisation presupposes a common goal and requires negotiating and addressing a range of governance challenges, including the trade-offs and tensions between different mandates and the power dynamics among stakeholders.[634]

Some types of institutional arrangements better facilitate One Health governance than others. African countries especially are playing a leading role in

establishing national and regional coordination bodies and initiatives that drive One Health operationalisation, implementation, and institutionalisation,[635–639] as exemplified by a review of 315 One Health initiatives that had been established in sub-Saharan Africa by 2021[619] and a more recent proposal for a district-level One Health service delivery model in Kenya.[640] Several One Health initiatives have also emerged in south Asia, including operational One Health strategies in Bhutan and Bangladesh,[638] along with efforts to develop One Health priorities for the region.[616,641] Integrating One Health into institutions that are still under development or undergoing reform therefore seems to be less demanding than transforming those that are already established.

Achieving a global One Health governance scenario that resonates with our proposed socioecological systems perspective and approach (as discussed in section 1) and One Health ethos (panel 2) demands a global reorientation of values, interests, goals, resource allocation, and distribution of authority and power.[627] Multiple challenges need to be addressed, including fragmentation among initiatives, a lack of coordinated and cohesive strategic direction, insufficient stakeholder representation (especially from LMICs and marginalised communities, including local and Indigenous populations), little engagement among key segments of the private sector, structural barriers to wider collaboration (including inadequate funding for multiministry and multiagency collaboration), and gaps in monitoring and evaluation.[50,642]

A possible avenue to realising One Health governance could be through establishing a global One Health governance framework and structure, which would provide technical guidance and evidence-based support for capacity building for not only well recognised One Health concerns, such as infectious diseases and AMR, but also NCDs, food systems challenges, and the wide range of socioecologically interconnected health and sustainability challenges. Such a One Health structure could model established science–policy interfaces, such as the IPCC and IPBES, but should also review and advise on evolving policy issues and support or perform external evaluations of progress towards One Health operationalisation, implementation, and institutionalisation. The proposed structure could be a new entity or, ideally, the already existing structures (the OHHLEP-supported Quadripartite and their respective regional coordinating mechanisms) could evolve to fulfil these functions, if provided with sufficient resources, including funding, a dedicated full-time workforce, and legal authority. This governance framework should leverage established institutions and governance arrangements where they exist and create new ones where there are gaps. Proposing the inevitable institutional trade-offs and predicting the ideal outcome is beyond the scope of this Commission and current state of progress, but clarity can emerge and evolve through the following, five-step process, which should be pursued under the leadership of WHO, WOAH, UNEP, and FAO (effectively the One Health Quadripartite), with the support of the OHHLEP, and in collaboration with all other relevant international organisations (eg, the World Bank and UN Educational, Scientific and Cultural Organization).

First, these parties should commit to an ambitious vision for the scope of this global structure and governance framework.

Second, they should develop theories of change and take stock of the current state, measured against the vision and scope, including a methodologically rigorous appraisal of what exists, how is it performing, and where reform and novelty are needed.

Third, a future state of global governance for One Health should be designed, taking into account where issue-specific bodies play a role, where global One Health interests are better served by grouping, and how relationships and authorities relative to the international One Health organisations will work. This future state should comprise four types of bodies: governance bodies to define the mandate and strategic direction and perform high-level advocacy; resource mobilisation bodies to generate and manage funds; science and evidence bodies to generate and synthesise evidence, design technical frameworks, and advise; and stakeholder bodies to drive engagement and manifest partnerships for action.

Fourth, global and multilevel discussion should be engaged among all stakeholders (eg, on whether something is supported by stakeholders, why, and what design improvements are suggested). At a minimum, the following stakeholder groups should be meaningfully engaged: global, regional, national, and community political leaders and bodies; the research community; civil society and communities; the private sector, including industry; funders, including philanthropy; and implementors across all stakeholder categories, including governmental and non-governmental organisations.

Fifth, any new legal mandates that are necessary for effective implementation of the One Health framework should be established. Accountability mechanisms and any necessary transition arrangements for integrating existing mandates to new structures should also be established. Implementation should be accompanied by monitoring and evaluation, which will inform timelines and procedures for review, as well as revision and evolution as necessary.

The negotiations surrounding the WHO Pandemic Agreement could provide an impetus for establishing a global One Health governance framework and structure that would oversee and provide technical and scientific support during implementation of the agreement, including by addressing emerging policy challenges and contributing to negotiations. In addition, the inclusion of One Health in the WHO Pandemic Agreement could promote integrated One Health surveillance systems

towards connecting and sharing data on infectious pathogens and other health risks in wildlife, companion animals, livestock, humans, and the environment (as discussed in section 2), among other benefits. This inclusion could also facilitate the adoption of a standardised evaluation framework, including appropriate metrics and indicators, for evaluating One Health initiatives (eg, surveillance and interventions).[643] Importantly, the struggle to conclude the WHO Pandemic Agreement negotiations, and the controversy around the inclusion of the One Health and pathogen access and benefit-sharing elements in particular, are examples of the challenges faced in negotiating interests related to national sovereignty and addressing the power imbalances between LMICs and HICs.[644,645]

Despite the need for One Health evaluation, including in the context of the WHO Pandemic Agreement, and despite advances in One Health operationalisation, implementation, and institutionalisation, global consensus on how best to measure One Health progress has not been reached. Although several economic evaluation frameworks, metrics, and valuation methodologies of potential relevance for One Health exist (tables 1, 2, and 3), and although some One Health-specific evaluation frameworks have emerged in recent years, including the Global One Health Index (as discussed in section 6.5), no single tool or integration of existing tools has been adopted on a large scale. The establishment of national One Health action plans and the integration of One Health into pre-existing national strategies or policies therefore provide opportunities for identifying indicators and developing contextualised One Health evaluation frameworks.

One Health governance should ensure continuous involvement of communities (including Indigenous communities) and all other stakeholders. Transdisciplinary processes that prioritise early involvement of local stakeholders are important in this regard and for successful, context-specific implementation of One Health interventions. The Preventing Zoonotic Disease Emergence initiative is one example of an endeavour that has prioritised inclusive and participatory processes.[646] The One Health Quadripartite's One Health Joint Plan of Action and its implementation plan, which includes One Health activities, deliverables, and timelines at both local and global levels, could provide much-needed guidance for harmonising global and local governance.[174] In addition, the Joint Plan of Action's six interdependent action tracks are all highly relevant for local communities. These action tracks cover prevention, surveillance, and control of emerging, re-emerging, and endemic zoonoses; AMR; and reduction in food safety risks, and promote a One Health-oriented strengthening of health systems and a better integration of environmental issues. Unfortunately, the Joint Plan of Action does not explicitly address NCDs in its current plan, despite the relevance of NCDs within a One Health perspective (as discussed in section 5). National implementation of the Joint Plan of Action will require consideration of governance processes at different scales. For example, to enhance the contributions of One Health towards strengthening health systems, local authorities and stakeholders from the health-systems building blocks should participate in the decision-making process.[647] Furthermore, local, interdisciplinary, transdisciplinary, and multisectoral workforces need to be established, and equitable, cost-effective financing needs to be secured for One Health operationalisation, implementation, and institutionalisation at all governance levels (as discussed in section 8.2.2).

Governance for One Health entails integration of the One Health approach into all relevant policy domains. This integration will help to promote healthy socioecological systems and to reduce the unintended consequences of some health interventions, including the asymmetric distribution of attention or resources. When expanding One Health across policies, tensions between disciplines and sectors are likely to emerge, and a solution will require robust One Health infrastructure, sufficient political will, One Health leadership and stewardship for healthy socioecological systems, a balanced negotiation of varying priorities, and exploiting the unifying power of joint One Health advocacy. To achieve viable One Health governance, how various stakeholders stand to win or lose from specific One Health policies and implementation pathways; what can be done to minimise harm and unintended consequences; and how inclusion, transparency, adaptability, and consensus can best be ensured need to be examined. These questions and others warrant urgent consideration by all One Health stakeholders and demand transformative and sustainable change at all governance levels.

In summary, the aim of One Health governance is to facilitate and sustain a normative shift in service to equitable, sustainable, and healthy socioecological systems, anchored in the One Health principles proposed by this Commission (panel 2). This aim demands accountability from all stakeholders, as well as interdisciplinary, transdisciplinary, and multisectoral collaboration, enabled and supported by One Health coordinating mechanisms and infrastructure, institutional innovation, and sufficient financing (as discussed in section 8.2.2).

8.2 One Health economics and funding

8.2.1 The need for an economic paradigm shift

As discussed in section 6.5, several studies have shown the costs and benefits of One Health interventions compared with non-One Health interventions.[485,486] However, to address intersecting global health and sustainability challenges, such as climate change, pollution, biodiversity loss, land use change, increasing emergence of zoonotic infections of pandemic potential, AMR, NCDs, food security concerns, and water scarcity,

new One Health-based evaluation frameworks and indicators need to be created, and the prevailing growth-based and anthropocentrically oriented global economic system should be radically rethought. Improvement in economic indices, such as GDP, have been shown to be correlated with poverty reduction and overall improvement in the health status of billions of people in LMICs throughout the past decade.[506,648] However, the aforementioned gains have not been equitably achieved and distributed,[649] and have come with devastating costs to the environment, including wildlife and ecosystems.[650–652] The so-called green growth proposition that GDP-defined economic growth can be decoupled from harmful environmental impacts,[653–655] and the suggestion that this can be realised equitably,[656] are compelling. However, evidence that these ideas can be realised at the rate and scale necessary to sustain the planet is scarce.[657–659] Natural capital is finite. As a global society, we are already operating unsustainably and inefficiently beyond the planet's capacity. In many wealthy nations, the marginal benefits of increased GDP are diminishing or are nearing or have reached a point at which the benefits of more growth are outweighed by the costs to human welfare and the environment.[649,660–663]

At the heart of a much-needed economic paradigm shift are crucial questions about how to replace the current resource-extracting, ecologically destructive, and inequity-generating global economy with one that prioritises equity, sustainability, and wellbeing.[664] Current blueprints and initiatives that advocate for alternatives to growth and that support such a shift include Doughnut Economics,[665,666] the Circular Economy,[667,668] and the Wellbeing Economy.[669,670] Arguably, the most recent high-level rethinking of the relationship between sustainability, wellbeing, and the global economy has been advanced by the WHO Council on the Economics of Health For All. This thinking reframes health as a public policy objective, with emphasis on the interdependent relationship between the economy and health, and as both an economic sector and a crucial objective for all other sectors and global economies.[671] This initiative, like the Geneva Charter for Well-Being, recognises that the conceptualisation and measurement of wellbeing extends beyond classic economic indices to include physical, psychosocial, and spiritual wellbeing, as well as human rights, social and environmental justice, sustainable development, equity, and peace.[476]

A systemic and socioecological One Health transition will require prioritisation of sustainability and the health of humans, other animals, plants, and the shared environment. Heterodox economic paradigms, which not only promote a reduction of material excess, but also recognise the damage that growth has caused, including in the form of climate change, pollution, biodiversity loss, land use change, and increased emergence of zoonotic infections of pandemic potential, require a change in mindset, globally and at all levels of governance and society. These paradigms also recognise a move towards meaningful alternatives to overconsumption that prioritise wellbeing among humans and all other life, as well as the restoration and protection of ecosystems. Funding for the research that will inform such economic paradigm shifts is needed.

8.2.2 Financing One Health within current systems

The realisation of an economic paradigm shift will take time and must therefore be pursued in tandem with efforts to mainstream and institutionalise One Health within the prevailing global economic system. This aim necessitates innovative financing. Tracking funding flows and financing models for One Health at various governance levels is an important early step towards measuring the current gaps. Multipartner trust funding provided by the Quadripartite Joint Secretariat on AMR and the World Bank-led Pandemic Fund could provide early data.[672,673] The World Bank estimates that approximately US$1·9 billion to $3·4 billion is required annually in LMICs to build and operate effective disease prevention and control systems. In 2021, the World Bank had more than $1·5 billion invested in One Health operations, with an emphasis on reducing risks from emerging infectious diseases.[674] In addition, support for One Health-aligned research, capacity building, and operationalisation at local and national levels in many countries has been provided by several global health funders and can be measured and tracked once clear criteria are established. These criteria should clarify what qualifies as One Health funding, as not all funds that support One Health causes are labelled as such.

A range of national and international financing mechanisms can help to mobilise the funds and other resources necessary for pursuing the One Health ambition of equitable, sustainable, and healthy socioecological systems, but equitable One Health financing must be prioritised, and the funding disparities that have existed within the One Health field must be addressed. These disparities include the disproportionate funding between the human, animal, and environmental sectors and the disproportionate attention that classic One Health concerns, such as zoonoses, have received compared with environmental concerns, such as climate change, biodiversity loss, and pollution. A collaborative process must be established to identify an evidence-based set of high-priority investments for One Health that ensure an equitable distribution of resources across the socioecological domains of One Health concern; between human, animal, and environmental sectors; and between HICs and LMICs, thus addressing international power imbalances and empowering LMICs.

Innovative finance is a set of solutions that aim to raise and channel both public and private funds and resources beyond those provided through traditional funding mechanisms (particularly development aid) and towards

persistent global concerns.[675] Innovative financing might involve microcontributions, debt-to-health swaps, market-based financial transactions, and support for public–private partnerships. Examples of innovative financing for One Health implementation specifically could include a Global Fund-inspired model[76] of development impact bonds,[676] or the Global Financing Facility, which is a country-led global partnership that provides catalytic financing and technical assistance to LMICs to develop and implement national health plans that scale up access to affordable, high-quality care for women, children, and adolescents.[677,678] Key to the Global Financing Facility is blended finance,[679] which combines commercial funding with loans that are extended on more generous terms than market loans (ie, concessional financing),[680] and which the Organisation for Economic Co-operation and Development defines as "the strategic use of development finance for the mobilisation of additional finance towards sustainable development in developing countries".[681] Various instruments for addressing debt, including bond offerings (eg, development impact bonds, social bonds, green bonds, and sustainability bonds), could be leveraged by One Health. The International Finance Facility for Immunisation, which is crucial for Gavi, the Vaccine Alliance, issues vaccine bonds on capital markets against long-term donor pledges and is another form of innovative impact investment and financing that could be amenable to One Health applications.[682,683]

Innovative finance in many instances involves leveraging capital from the private sector based on public-sector funders or philanthropists providing an attractive return on investment. This model naturally risks leaning towards more profitable and scalable products and services (eg, drugs and vaccines targeting pandemic-prone diseases) and neglecting preventive and holistic One Health measures. In other words, return on investment is a precondition for economic participation from private investors.[684] Strengthening the private sector's role in governance for One Health should therefore avoid a so-called financialisation of health approach, which has geoeconomic and geopolitical consequences[682] including the reinforcement of a financial culture in which short-term and commercial gains are prioritised over the long-term One Health goal of equitable, sustainable, and healthy socioecological systems. Additionally, awareness is needed as to the influence of other private-sector entities, such as private foundations,[683] which have vast resources and donate to governments and international organisations, such as WHO and UNICEF. These entities also directly influence national and international policies. This influence is not necessarily negative, but decisions of consequence for the prioritisation of One Health policies and interventions should nevertheless not be subject to undue private influence, be it from private for-profit entities (ie, business) or private not-for-profit entities (eg, foundations, charities, and trusts).[685–688]

For more than a decade, the World Bank has incorporated One Health into its development financing portfolio and has generated important reference material for operationalising, implementing, and institutionalising the One Health approach in LMICs.[51,68,689] In 2022, a One Health investment framework to reduce pandemic risks was suggested by the World Bank, with a strong emphasis on One Health and disease prevention,[690] and One Health has both been mainstreamed into existing World Bank funding mechanisms and programmes and included in new ones.[690,691] In June, 2022, the World Bank also confirmed the establishment of a funding programme for strengthening pandemic prevention, preparedness, and response, based on a financial intermediary fund arrangement and with a strong focus on One Health.[672,692] With technical support from WHO, the World Bank's new financial intermediary fund has a strong focus on One Health.[672,693]

The need for sustained and sufficient One Health financing applies to both LMICs, where funds for One Health capacity building are delivered under the framework of research grants and development assistance, and HICs, where the future of funding for One Health is uncertain and where funding shifts are needed. With most funding in LMICs coming from overseas development assistance, priority setting, design, and implementation could be biased towards the interests of HICs or development partners. Therefore, the importance of transparent and equitable funding between institutions and researchers in LMICs and those in HICs, as well as transdisciplinary approaches to inclusive participation and community engagement, cannot be overemphasised. The Research Fairness Initiative has developed a series of dynamic tools that encourage fair research and innovation partnerships as the key to research excellence and innovation,[694] which can be applied directly to One Health.

Both financing strategies and the application of funds for One Health should be carefully coordinated among donors to ensure that global objectives, such as those of the WHO Council on the Economics of Health for All,[671] and national action plans, particularly in countries within the same regions, are aligned and receive adequate attention, including with regard to outcome monitoring, evaluation, and reporting (panel 8). Strategic partnerships among funders to target specific One Health challenges that require crucial multisectoral actions need to be fostered. Long-term goals and commensurate investments are also needed, given the temporal and spatial dynamics of socioecological system changes. As an example, the systemic integration of One Health into formal educational systems will require strategic long-term investment.

In summary, a paradigm shift in local, national, and international budgetary allocation and financing is urgently needed, along with novel economic frameworks that are focused on realising and sustaining equitable and healthy socioecological systems.

Panel 8: **The private sector in One Health: a complex landscape in need of change**

Businesses and the private sector are broadly growth oriented and focused on solvency and financial sustainability, as defined by the global financial system. Therefore, if an economic activity or project that informs investment decisions is One Health-aligned, share price, profitability, and financial sustainability will be redefined and the company will be positioned to fulfil its profit-oriented mandate without costs to, and potentially while advancing, health and sustainability.

From a corporate pharmaceutical perspective, the structure of the research and development pipeline is driven by the cost of developing products, the likelihood of them being approved, and the expected market attractiveness and profitability.[695,696] The returns generated by One Health-oriented investments often do not fit into the short-term profit maximisation schemes that are prioritised:[697] for example, the speed with which mRNA vaccine technology was channelled into the development of vaccines for COVID-19 only in 2020 after having been discovered in the 1970s, the exceptional profitability within the global market for mRNA vaccines during the COVID-19 pandemic,[698,699] and the vaccine inequity that prevailed. Market conditions therefore need to be economically rebalanced to allow for One Health-aligned pharmaceutical investment in research and development.[700,701] Private-sector engagement in One Health is needed to actively co-shape One Health-oriented markets, and to codesign processes that can catalyse the innovation necessary to advance concrete, mutual One Health goals.[702]

A strong case can be made for promoting a One Health-oriented private sector. By reorienting consumer views, creating possibilities for consumption choices that are One Health-aligned, and conceptualising business as a force for good,[703,704] companies could achieve sustainability-oriented, long-term aims in ways that enhance innovation, brand reputation, stakeholder relations, and sales, thus synergising societal value creation and the financial interests of companies. A One Health lens can play a pivotal role in creating long-term and stakeholder-oriented business models that align with other indicators. In terms of financial performance, investors would consciously apply global health-based and, by extension, One Health-based non-financial factors in their analyses and assessments of investment opportunities.[705,706]

Several factors, including donor-driven and technocratic agendas, short-term funding, market failures, and economic conflicts of interests pose challenges to multisectoralism, interdisciplinarity, and transdisciplinarity. Crucial questions have been raised about the extent to which government financing aimed at incentivising private investments in research and development are operating at the expense of health equity. The Trade-Related Aspects of Intellectual Property Rights (TRIPS) agreement, for example, incentivises research and development for vaccines, diagnostics, medicines, and other interventions by offering a period of patent protection that enables patent holders to charge considerably higher prices than the competitive market would allow, with potentially severe consequences for affordability and equitable access. Moreover, as a market force modifier, TRIPS does not incentivise research and development for medicines and other interventions for which no market exists (eg, medicines and interventions targeting diseases suffered by people who cannot afford them at any price and for whom government safety nets are not available). TRIPS is hence among the existing market force modifiers that require revision or mitigation (or both) if the One Health approach is to succeed. TRIPS underscores the incompatibilities between the One Health approach and the prevailing economic order and market system, the importance of addressing how the private sector currently influences global health governance, and the need for a One Health-informed, sustainability-oriented, and equity-oriented alignment of private and public contributions to global health and development.

Engagement of the private sector is essential for implementing the One Health approach, particularly when pandemic prevention, preparedness, and response is taken into consideration. For example, during the COVID-19 pandemic, big tech companies profited considerably, but were also crucial to generating, directing, and redirecting the public to the most up-to-date, verifiable information, in addition to developing and repurposing systems and technologies to support the provision of health care and other services.[707]

8.3 One Health knowledge

Equitable practices of knowledge production, integration, and sharing are an essential premise for advancing the One Health paradigm shift towards healthy and sustainable socioecological systems.[708,709] Knowledge involves a wide repertoire of cognitive domains, as well as values, attitudes, and beliefs, which emerge, evolve, and are negotiated and disseminated through multiple channels, including education, media, and personal and professional experience. Fundamentally, the power of One Health is in the integration and real-world harnessing of diverse forms of knowledge, within an agenda that prioritises inclusivity, interdisciplinarity, transdisciplinarity, co-construction, and shared accountability. As such, knowledge constitutes a crucial avenue for operationalising, implementing, and institutionalising One Health.

To achieve the goal of healthy and sustainable socioecological systems, a global, society-wide appreciation of One Health values (the ethos proposed by this Commission in panel 2) is needed. One Health must also continue to evolve in alignment with these values. Reaching these goals requires recognising that One Health spans a vast range of knowledge and practice and appreciating the added value that is generated by integrating the unique contributions of each discipline,

sector, and knowledge tradition that One Health comprises. In addition, One Health knowledge must be both global in reach and context-relevant (ie, accessible to and applicable for all people around the world), as well as intergenerational by design, with an emphasis on bidirectional dialogue and flows of knowledge. Young generations are socially engaged, digitally connected, and in possession of tacit knowledge that can enrich the discourse around sustainability and health, as well as engender the innovation needed for operationalising, implementing, and institutionalising One Health. One Health knowledge must also be inclusive, including with regard to the knowledge possessed by local communities and Indigenous knowledge systems, which are grounded in the inextricable link between the health of people, animals, plants, and the wider environment, and which have built a rich yet marginalised knowledge base around this link for thousands of years.

8.3.1 Advancing the co-production and dissemination of One Health knowledge

Given the silos within which disciplines, professions, governmental ministries, and funders continue to operate, the current systems for education, research, and, at large, knowledge production, exchange, integration, translation, and dissemination are predominantly not structured to accommodate and advance the One Health paradigm shift. Institutional reorientation and increased financial investment in interdisciplinarity and transdisciplinarity are needed, with several pan-university One Health initiatives and some funders who have initiated One Health-focused and One Health-aligned financing streams for research leading the way.[710,711] The One Health approach should be integrated throughout all educational levels and programmes, and especially in domains in which One Health is highly relevant but receives insufficient attention, such as medical schools and the health sciences more broadly. This integration is important to equitably advance health throughout the socioecological system and ensure that all know how they can contribute and develop the capabilities to do so.[712]

To address the current global health and sustainability challenges, One Health education and research capacity must be enhanced globally, which requires increased investments. Institutions in LMICs especially require increased investment, as they host several One Health networks and initiatives but are constrained in terms of resources (as discussed in section 8.2.2). One way to strengthen domestic capacity for One Health in LMICs is by establishing and sustaining partnership networks or consortia for international collaboration, not only between HICs and LMICs, but also within and between LMICs. Three examples of such networks are the Southeast Asia One Health University Network,[713] the Africa One Health University Network,[714] and the Africa One Health Network.[715]

Furthermore, greater intellectual and practical integration of complex adaptive systems,[716,717] post-normal science (a field dedicated to problem solving in contexts of uncertainty, high stakes, and urgent needs for decisions), socioecological systems theory,[718] and the concept of resilience within One Health epistemology and pedagogy are needed.[73] Methodologies from futures thinking and foresight that promote narratives, creative problem solving, diverse possibilities, and group analysis of complex science-policy problems should also be mainstreamed, and these should engage with megatrends and potential scenarios in the interest of developing robust, resilient, reflexive, and adaptable policies and systems.[719] Additionally, the fields of sustainability law and legal epidemiology could offer opportunities to define legislative and policy priorities across different sectors.[720]

Moreover, additional efforts in institutional and policy analysis are needed to identify opportunities for and challenges to One Health operationalisation, implementation, and institutionalisation, considering wider political economies. In this regard and others, One Health knowledge integration entails appreciating the differences between diverse knowledge systems and bridging the gaps that persist between academia, policy, the private sector, and local communities, in the interest of fostering evidence-to-policy and knowledge-to-action translations. As an example, strong, meaningful, and respectful engagements with local communities (eg, farming and fishing communities) are beginning to emerge in some One Health collaborations worldwide.[721,722] One Health collaborations that explicitly include Indigenous populations and knowledge are especially needed.[723]

8.3.2 Education, professional development, and the cultivation of a One Health citizenry

One Health operationalisation, implementation, and institutionalisation will not be possible without far-reaching and sustained efforts in education, knowledge co-creation, workforce development, and the cultivation of a universal and society-wide One Health citizenry, realised across different scales of funding, contribution, vision, and intensity, from modest grassroots efforts to sizable international networks.

One Health must be embraced as the overarching framework for the education and training of a new cadre of professionals who will be willing (possessing the right mindset), able (equipped with the knowledge), and enabled (supported by empowering structures) to drive systemic and sustainable transformations that safeguard and advance health among humans, other animals, plants, and the myriad of other biotic and abiotic elements in our shared ecosystems. Curriculum and pedagogy reforms within the education sector are necessary, including the adoption and implementation of a standardised framework for core One Health competencies (ie, "the desired

fundamental knowledge, skills and attitudes of a person trained and working in One Health"[724]), at various levels of higher education and professional training. The Network for Evaluation of One Health conducted a review of previously proposed One Health competencies and competency domains and, taking into consideration the OHHLEP definition of One Health and a conceptualisation of One Health that is increasingly socioecological systems-oriented, published an updated collection of nine core One Health competencies.[724]

Moreover, national One Health pedagogical task teams with diverse disciplinary membership can facilitate participatory processes, including for the purpose of co-designing educational and training materials and mainstreaming One Health within the education sector, including through open-access, online courses.[724–727] Within the education sector, courses and programmes, including in practical field settings, can allow students to apply One Health principles and engage in experiential learning. Examples are internships, exchanges, field research days, and greater academia–policy–civil society collaborations that support One Health translation, such as from evidence to policy and from knowledge to action. Professional One Health certification can be developed and, because One Health knowledge will continue to grow and evolve, continuing professional education is essential and the concept of lifelong learning must underpin One Health education and workforce development. In terms of content, One Health education must emphasise not only material realities, such as biology, ecology, and epidemiology, but also their social, political, economic, cultural, and philosophical dimensions. This emphasis requires meaningful engagement with faculties of the social sciences, which are classically marginal in One Health circles. Moreover, as the true power of One Health knowledge is in its application in the real world, professionals would also need foundational training in leadership and interpersonal skills, including communication, negotiation, teamwork, and multisolving (ie, the ability to address multiple challenges through a cohesive investment and solution). The One Health education framework must also embrace the vision and recommendations of the 2010 *Lancet* Commission on health professionals for a new century and expand its purview to include all professionals as transformative change agents for the worldwide advancement of equitable, sustainable, and healthy socioecological systems.[728]

The cultivation of a universal, society-wide One Health citizenry must begin by fostering One Health literacy among children and young people, through the incorporation of One Health principles and introductory scientific content in primary, middle, and secondary education. This content should encompass the values, technical knowledge, and practical skills necessary to translate One Health into daily practice, be fully transparent about the facts, highlight where uncertainty exists, avoid propaganda-type pessimistic framings of anthropogenic change, be sensitive to age, and emphasise positive and solutions-oriented discussions.[729] Initiatives such as One Health Lessons, which is a global library of One Health syllabi for different grade levels that has been translated into multiple languages, offer important contributions to empowering teachers to bring One Health into their classrooms.[727] One Health literacy also presupposes media literacy (ie, a capacity for accessing, analysing, evaluating, and creating media in a variety of forms), as well as a transformation of the relationship between media and science, with several trends paving the way. These trends include science journalism, participatory solutions for integrating science communication within research projects, and other efforts to make science-based information publicly accessible through digital media, social media, and other platforms that researchers use to communicate directly with the public.[730–733] More research is needed into the potential value and risks of such trends.[734] Also needed is increased understanding of the ways in which One Health can be embedded in journalism, with journalists embracing a One Health approach to investigation and reporting that is grounded in a holistic appreciation of the links between the health of humans, animals, and the environment.[735]

Operationalising One Health will also require strong leadership and an understanding of the concept at high levels of the political spectrum, as is being advanced by the One Health Quadripartite and World Bank.[174,690] Strategies for promoting, translating, and disseminating One Health are also needed to help key stakeholders (including political leaders, policy makers, and private-sector actors) to become more One Health literate, to promote holistic thinking around health at the human–animal–environment interface, and to ensure that One Health knowledge and innovation is integrated within sound decision making.

In conclusion, the emergent One Health knowledge system—built on a continuously expanding and inclusive knowledge base, diverse and competent professionals equipped to become change agents, and empowered citizens who espouse One Health values and principles—has the potential to generate transformative, systemic change for the achievement of sustainable health for all constituents of the socioecological system.

9. Recommendations of the *Lancet* One Health Commission

One Health knowledge and practice are rapidly evolving. Coupled with the many variables involved in One Health, this evolution means that interactions and outcomes are constantly changing. Following the science and being able to pivot when called for is crucial, even if not conventionally politically expedient. Policy makers must be trusted. When adjustment is needed, all must be on board, which presupposes that recommendations and all associated metrics, targets, and indicators are

Panel 9: Recommendations from the *Lancet* One Health Commission

1 Institutionalise One Health within global, regional, and national governance architecture

At the global level, a One Health governance framework, led by a sufficiently resourced One Health structure (ie, with adequate funding, a dedicated full-time workforce, and legal authority) should be developed. Ideally, the One Health Quadripartite could evolve to fulfil these functions. Established institutions and governance arrangements should be leveraged where they exist and new ones should be developed where there are gaps. The following process is advised:

A Commit to an ambitious vision for the scope of this global structure and governance framework, among all relevant international organisations
B Develop theories of change and take stock of the current state: appraise what exists, how is it performing, and where reform and novelty are needed
C Design a future state, comprising governance bodies, resource mobilsation bodies, scientific bodies, and stakeholder bodies
D Engage global and multilevel discussion among all stakeholders (eg, political leaders, researchers, civil society, private sector, and funders)
E Establish new legal mandates for novel establishments, transition arrangements for the integration of existing establishments into new structures, and accountability mechanisms
F Implement the framework, monitor and evaluate, and revise and evolve as relevant

At the regional and national levels, all government ministries, together with all relevant sectors and stakeholders, should continue to develop and implement governance reforms, including: One Health strategies and action plans, One Health platforms and multisectoral coordinating mechanisms, context-adapted monitoring and evaluation frameworks, and joint funding for multiministry and multiagency work. At all levels, diversity (including disciplinary, sectoral, cultural, and gender) and community engagement must be ensured.

2 Achieve coherent One Health policy and governance through One Health in all policies

Embed One Health principles (ie, holism and systems thinking, epistemological pluralism, equity and egalitarianism, and stewardship and sustainability) and explicitly address the links between human, animal, plant, and ecosystem health within existing and emerging codes, conventions, frameworks, guidelines, regulations, agreements, action plans, agendas, and policy documents. Primarily responsible should be the proposed global One Health structure (recommendation 1), including the international organisations it convenes, as well as a diverse, interdisciplinary, and multisectoral commission of scientists and policy makers. These parties should also be tasked with the development of a joint action plan for One Health in all policies and a guide or toolkit for implementation at the national and subnational levels.

At the national and subnational levels, One Health platforms and multisectoral coordinating mechanisms, together with diverse, interdisciplinary, and multisectoral commissions of scientists and policymakers, should identify appropriate policy windows and integrate One Health in all relevant national and subnational strategies, action plans, and policies. Representation from Indigenous and local communities should also be ensured.

3 Integrate human, animal, and environmental health and surveillance systems

Integrated One Health surveillance systems should be developed and implemented to monitor infectious diseases, antimicrobial resistance, non-communicable diseases, and the overlaps and human-mediated changes to the socioecological system that drive the emergence, spillover, and spread of infectious agents (eg, wildlife habitat loss, land use change, biodiversity loss, and climate change). Preconditions for successful One Health surveillance systems should be ensured, including legal provisions to facilitate equitable sharing of intellectual property; frameworks for data sharing, harmonisation, and integration or triangulation; operational capacity; a fair distribution of costs and gains (globally and across sectors); and continuous engagement with communities (including Indigenous).

Above and beyond One Health surveillance systems, One Health systems, potentially conceived more broadly as integrated human, animal, and environmental health systems, are a long-term vision. Over the next decade, integration of select health-care sites and systems can be piloted at the local level. At the international level, the proposed One Health structure (recommendation 1) and other relevant stakeholders should develop a joint action plan for One Health systems and thereafter operationalise, implement, and institutionalise One Health systems as relevant.

4 Achieve a transformation of global economics that prioritises equity, sustainability, and wellbeing as the key measures of progress

At the global level, a multisectoral commission of UN agencies, stakeholders, and experts, including from the private sector, should:

A Appraise existing, generate new, and disseminate evidence regarding the inadequacy of gross domestic product-defined growth for achieving and sustaining healthy socioecological systems; viable alternatives should be identified
B Facilitate the global, regional, and national adoption of economic metrics that are aligned with the One Health ethos and, as needed, develop novel economic metrics to quantify and measure equity, sustainability, and wellbeing

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(Panel 9 continued from previous page)

5 Operationalise, implement, and institutionalise adequate, innovative, transparent, and equitable financing for One Health

Novel funding mechanisms for One Health should be identified or established. Strategic partnerships among funders should be forged to ensure sufficient financing for One Health implementation and, therein, an equity-oriented distribution of resources across sectors and between low-income and middle-income countries and high-income countries. The World Bank should drive these efforts, together with regional development banks and the proposed One Health structure (recommendation 1). Priority challenges to be targeted span climate change, biodiversity loss, infectious diseases, antimicrobial resistance, non-communicable diseases, and pandemic preparedness. This process should include the following:

- A Existing funding mechanisms and programmes, including the World Bank-led and WHO-supported Financial Intermediary Fund for Pandemic Preparedness and Response, should be leveraged for One Health; other innovative financing models and novel financing partnerships of potential relevance for One Health include widely sourced microdonations, blended finance, novel private–public partnerships, and impact investments, but more traditional funding mechanisms (eg, official development assistance, philanthropic donations, fiscal policies that redistribute income and wealth, and smart taxation) should also be mobilised
- B Cases that show return on investment should be documented
- C Any remaining needs for financing should be described and appropriate, and novel funding mechanisms should be established, if and as needed

6 Harness the full potential of the private sector, including its extensive resources, influence, and amenability to innovation, to become One Health leaders who promote equitable, sustainable, and healthy socioecological systems

The following combination of One Health-aligned corporate governance reform, innovation, public–private partnerships, and sustainable supply chain management is advised:

- A Companies must incorporate the One Health principles of holism and systems thinking, epistemological pluralism, equity and egalitarianism, and stewardship and sustainability into their corporate social responsibility policies, long-term business strategies, workforce training, and environmental, social, and governance reporting frameworks
- B Private-sector entities involved in health care, biotechnology, pharmaceuticals, food production, and agriculture should increase investments in One Health-aligned research and development and promote the equitable production of healthy and sustainable products in partnership with low-income and middle-income countries, including vaccines, medicines, and food
- C Companies in industries such as agriculture, food production, and retail, must implement socioecologically healthy and sustainable sourcing, production, and distribution practices; this implementation must include the promotion of animal welfare, environmental restoration and conservation, and the abandonment of socioecologically harmful practices, such as deforestation, encroachment on wildlife habitat, unsustainable harvesting, and pollution
- D The private sector needs to adopt integrated surveillance systems and data-sharing frameworks across human, animal, and environmental domains, including in food production and agriculture, which includes real-time disease monitoring and response, compound libraries and technologies for the development of health products, and interventions to improve pandemic preparedness and health equity

7 Mainstream One Health throughout the higher education sector, as the overarching framework for the education and training of a new cadre of professionals to drive and sustain systemic transformations

Interdisciplinary and transdisciplinary One Health pedagogical task forces, interlinked at international, regional, and national levels, should be established to:

- A Achieve consensus around a core set of One Health competencies for higher education, integrate them within national higher education qualification frameworks, and institutionalise them within all accredited institutions of higher education, to guide and harmonise the integration of One Health across all disciplines, programmes, and curricula
- B Co-design an international One Health teaching repository of lecture materials and other resources that enables One Health to be flexibly integrated within all disciplinary curricula
- C Provide resources and support to increase capacity and capability for interdisciplinary One Health education within institutions of higher education and among faculty, building on evolving approaches to innovative teaching and learning that equip students to negotiate the need for urgent decisions and action in the midst of complexity and uncertainty
- D Establish and implement a monitoring and evaluation framework for assessing the institutionalisation of One Health competencies and mainstreaming of One Health throughout the higher education sector

8 Cultivate enabling conditions for One Health research and knowledge production

Establish interdisciplinary and transdisciplinary One Health research task forces, interlinked at international, regional, and national levels, whose mandate includes the following:

(Continues on next page)

(Panel 9 continued from previous page)

A Advance enabling conditions for One Health research and knowledge production, including a paradigm shift towards equitable, inclusive, and participatory knowledge production that engages local communities and Indigenous expertise, funding for interdisciplinary and transdisciplinary One Health research, and measures of success for researchers that move beyond publication numbers and impact factors to also encompass social and policy impact, as well as knowledge exchange within communities

B Provide resources and support to build capacity and capability for interdisciplinary and transdisciplinary

D Collaboration among researchers, appreciating that interdisciplinary and transdisciplinary research presupposes strong disciplinary expertise and new ways of thinking and collaborating

E Develop a global One Health research agenda and adapt it as relevant at regional and national levels, which will entail, among other things, mapping knowledge gaps, supporting research to address them, and annual assessment and reporting; knowledge gaps include One Health metrics and investment cases, gender and One Health, urban One Health, digital One Health, and One Health and non-communicable diseases, including brain and mental health

9 Achieve a One Health-literate global citizenry

One Health principles and knowledge need to be mainstreamed, which requires the integration of diverse knowledge systems, intergenerational knowledge exchange, and the development of a comprehensive evidence base that advances equitable, sustainable, and healthy socioecological systems. This integration also presupposes consistent, meaningful, and respectful engagement with Indigenous expertise and diverse local communities, and that knowledge will be translated into action and evidence into policy. The UN Educational, Scientific and Cultural Organization, the proposed One Health structure (recommendation 1), the proposed One Health pedagogy and research task forces (recommendations 7 and 8), and other key stakeholders should collaboratively develop a joint action plan for One Health literacy and oversee the process of adaptation and implementation at national levels. An overarching framework for monitoring and evaluating progress towards a One Health-literate citizenry should also be developed and implemented. The joint action plan should account for, but not be limited to, the following:

A One Health operationalisation, implementation, and institutionalisation must be advanced through public–private partnerships between the private sector and governments, non-governmental organisations, civil society, academia, and international organisations

B One Health literacy begins at birth; One Health knowledge and principles must be mainstreamed within all levels of preschooling and primary and secondary schooling

C One Health literacy implies building capabilities and capacity among the younger generation, who will shoulder the burden of the evolving planetary crises and be held accountable for change in forthcoming decades

D One Health literacy entails professional lifelong learning and development, facilitated through flexible, ongoing opportunities to acquire additional knowledge and skills

E One Health literacy at all levels of the political spectrum is a prerequisite for systemic governance transformations in service to equitable, sustainable, and healthy socioecological systems

10 Achieve a One Health-oriented transformation of food systems in service to equity, sustainability, and health

A joint action plan for equitable, sustainable, and healthy food systems (ie, food systems that sustainably and equitably meet the food and nutrition needs of the human population, while promoting health and wellbeing among humans, other animals, plants, and the environment at large) should be established and implemented at the international level, and translated at the national level. Implementation of this plan should take place through a process of equitable collaboration and policy integration across all relevant sectors and at global, regional, national, and subnational levels. The joint action plan should address key food systems challenges, including the triple burden of undernutrition, overnutrition, and micronutrient deficiency; zoonotic and foodborne diseases; antimicrobial resistance; greenhouse gas emissions and climate change; and environmental degradation and destruction driven by agricultural expansion. The One Health approach to food systems must also:

A Challenge the prevailing corporate systems that drive inequitable, unsustainable, and unhealthy production and consumption trends

B Ensure that the right to adequate food and food security are achieved in tandem with food sovereignty (ie, sustainable and equitable food production and consumption systems, in which power lies with local producers and consumers)

C Recognise the crucial role that the informal food sector plays in food security and livelihoods, as well as the need to support safer food production and exchange among informal producers and market stakeholders

D Critically examine the financialisation of the food sector and trade liberalisation, and resist the pervasive and aggressive promotion of inexpensive, highly processed, and unhealthy foods

E Hold industry and the private sector accountable for the health and sustainability risks that they bring to the food system, including by requiring the disclosure of environmental, social, and governance risks, to enable assessment and informed decisions among investors

F Advance and operationalise the EAT–*Lancet* Commission's call for healthy, high-quality food systems that, among other things, reduce food waste by half and promote a dietary transition in service to sustainability and health

co-developed through respectful, collaborative, equitable, and inclusive processes involving all stakeholders, at all levels of society, and across all sectors.

Multiple relevant disciplines, sectors, and nations are represented in this Commission, by scientists and practitioners who are engaged in One Health research, capacity building, and implementation in local communities and at national, regional, and international levels. Several relevant stakeholders are also insufficiently represented in this Commission, which is particularly the case for rural communities in LMICs, Indigenous communities, and the private sector.

We offer ten recommendations for One Health operationalisation, implementation, and institutionalisation (panel 9); more details on target groups and timelines can be found in the appendix (pp 16–26). We present these as concrete, targeted, and scientifically robust contributions to what must be an ongoing and inclusive process of establishing context-adaptable goals, metrics, indicators, and timelines. Alignment with the One Health Quadripartite's Joint Plan of Action 2022–26 and Guide to Implementing the One Health Joint Plan of Action at the national level has been prioritised.[174,736] The One Health High-Level Expert Panel has also published a theory of change and the One Health Quadripartite is planning to develop a monitoring and evaluation framework,[737,738] for which these recommendations are of value.

Conclusion

The *Lancet* One Health Commission provides a cutting-edge appraisal of where One Health has come from, where it is now, and what a viable future should be. The Commission explicates the importance of the environment and the criticality of the One Health approach to surveillance, infectious diseases, AMR, NCDs, health systems, and food systems. The Commission calls for individual, community, organisational, national, regional, and international action to advance equitable, sustainable, and healthy socioecological systems. To guide and galvanise this action, the Commission proposes a One Health ethos and articulates key avenues and recommendations for One Health operationalisation, implementation, and institutionalisation, with a focus on governance, economics, and knowledge. Ultimately, this Commission is a testament to the pivotal role that One Health can play in 21st century health and sustainability agendas, as well as its centrality to the ever-changing socioecological system.

One Health was not mentioned in the 2030 Sustainable Development Agenda; however, the impact of the COVID-19 pandemic brought into acute focus the fundamental interconnections between humans, other animals, plants, and a myriad of other biotic and abiotic elements in the ecosystem, and, consequently, how healthy sustainable socioecological systems could be achieved via a One Health approach. The consensus around One Health that has been built by the One Health Quadripartite and OHHLEP, which has been reinforced by the work of this Commission, is essential for addressing the threats to health posed by infectious diseases, AMR, NCDs, and planetary crises; harnessing data and artificial intelligence for disease surveillance and health-care delivery; forging equitable partnerships and inclusive collaborations; and generating necessary insight into socioecological interconnection. As such, One Health is a crucial catalyst in the pursuit of an equitable, sustainable, and healthy future, and must be central to the post-2030 global health and sustainability agenda.

Contributors

The *Lancet* One Health Commission is cochaired by ASW and JHA, with secretariats at the Centre for Global Health at the University of Oslo, the Department of Neurology and the Center for Global Health at the Technical University of Munich, and the Kumasi Centre for Collaborative Research in Tropical Medicine at the Kwame Nkrumah University of Science and Technology. ASW, JHA, and CMB drafted and revised the Commission together with an interdisciplinary and international group of co-authors serving as commissioners (HC, CGdN, BH, JZ, EMF, AO, WEH, BN-H, BA, DLH, FCJB, JS, JL, JC, JM, LB, MKL, MS, NX, OAH, PD, RRG, SSa, and TAS), advisors (AR, CA, EKR, GL, IC, LFT, OD, and YW), and scientific support staff (AKP, AH, LFR, MKA, and SSe). The second authorship position is jointly occupied by HC, CGdN, BH, and JZ who contributed extensively throughout the entire process of generating the Commission. The third authorship position is jointly occupied by specific working group leads (EMF, AO, GL, and WEH). HC and JZ also served as working group leads. DLH provided invaluable guidance on Commission formalities throughout the process of the Commission. All other authors are ordered alphabetically according to first name.

Declaration of interests

ASW is affiliated with two institutions that hosted commission secretariats and to whom funding for the Commission was allocated from two funding sources (the University of Oslo, which received funding from UiO:Life Science, and the Technical University of Munich, which received funding from the German Federal Ministry of Education and Research). CMB, AH, and SSe received compensation for their time spent working on the Commission as employees of the two institutions that were allocated funds for the commission (CMB at the University of Oslo, and AH and SSe at the Technical University of Munich). AH also supported the I-DAIR Pandemic Scientific Working Group in the role of a One Health expert. JHA and RRG are members of the *Lancet*–Chatham House Commission on improving population health post COVID-19. JZ, JL, MS, DLH, OD, and OAH are co-authors on papers in the *Lancet* Series on One Health and Global Health Security. CGdN received three grants for One Health activities in the 36 months before the submission of this Commission (Norwegian Government Grant for the National Wildlife Health Surveillance Programme Helseovervåkingsprogrammet for vilt, Research Council of Norway Grant for the arrangement of a Norwegian One Health Conference in November, 2022, and Horizon Europe European Joint Programmes One Health Grant for the Norwegian Veterinary Institute 2018–23). CGdN also received payment for a talk (at the World One Health Congress in Singapore, November 2022) and support for participation in two meetings and conferences about One Health (One Health Conference of the University of Queensland in September, 2022, and Canadian Global 1 Health Network annual meeting in Montreal in June, 2022). CGdN also had unpaid roles in the Wildlife Disease Association (president, 2019–21), Wildlife Population Health Specialty of the European College of Zoological Medicine (chair, 2018–23), and the International Union for Conservation of Nature and Natural Resources Species Survival Commission on Wildlife Health

(wildlife health specialist, 2018–23). EMF received grants for One Health research in the 36 months before this publication was submitted (from the Consultative Group for International Agricultural Research, UK Research and Innovation, and US Defense Threat Reduction Agency), as well as payment for a talk and support to attend a WHO meeting of relevance for One Health. EMF is also a member of the Senior Editorial Board for the CABI One Health Journal. AO received travel support from her institution, the Australian Centre for International Agricultural Research, to participate in a commission meeting. AR is funded by the Global One Health Network to coordinate and conduct research on One Health governance. JL is Chair of the International Working Group of the One Sustainable Health Forum (unpaid) and also coordinates and advises the Scientific Committee of the One Sustainable Health Forum (consultancy). JL received payment and travel support for speaking contributions to the World Veterinary Congress (Taipei, April, 2023), as well as travel support from the One Sustainable Health Foundation and Forum for the Geneva Health Summit (Geneva, May, 2022) and a meeting of the One Sustainable Health Foundation (Lyon, July, 2023). LFT received two grants to support One Health work in the 36 months before the submission of this Commission (German Federal Ministry of Economic Cooperation and DevelopmentOne Health Research Education and Outreach Centre in Africa and Deutsche Gesellschaft für Internationale Zusammenarbeit International Alliance against Health Risks in Wildlife Trade) and is also a Soulsby Foundation trustee. MS is affiliated with the World Organisation for Animal Health (employment period 2018–21 and contract period 2022–23). MS also received three grants for One Health work in the 36 months before the submission of this Commission (from the World Bank International Finance Corporation for animal health country projects in Vietnam and Mongolia, from the Ministry for Primary Industries, New Zealand to work with the National Animal Welfare Advisory Committee as Chair for animal health project contracts, and from the Wellcome Trust for the Research Strategy Group for the Antimicrobial Resistance Policy Accelerator project, York University, UK). MS also received travel support from the Global Strategy Lab at York University to participate in an April, 2023 workshop on Antimicrobial Resistance Global Governance in Toronto, ON, Canada and from the World Organisation for Animal Health to participate in the World Organisation for Animal Health Global Conference on Emergency Management in April, 2023. MS is on the Global Preparedness and Monitoring Board for the WHO and World Bank accountability mechanism for pandemic preparedness and response monitoring. PD received funding in the 36 months before the submission of this Commission from US Federal Agencies (National Institutes of Health, the US Agency for International Development, the Department of Defense, the Defense Threat Reduction Agency, and the National Science Foundation) to support research on emerging diseases. PD is also affiliated with the Global Virome Project, as the Secretary and Treasurer. All other authors declare no competing interests.

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